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VI.

SCREW PROPELLERS OF U. S. NAVAL VESSELS.

By Passed Assistant Engineer H. Webster, U. S. Navy.

The accompanying table and illustrations have been compiled in the belief that they will prove of interest to all marine engineers, and may assist in investigations tending towards a solution of the problem of the scientific design of screw propellers.

While certain general principles in connection with propeller design are now pretty well settled, the fact remains that some of the most important features are still determined empirically or, at times, by the whim of the designer.

This table, which contains the results of trials of fifteen ships, taken in connection with the reduced working drawings of the propellers, will at least give the careful student something on which to base empirical formulæ.

The data of the propellers themselves are absolutely correct, as are those of the hull dimensions. Those of the machinery are also thoroughly trustworthy, but, prior to the trial of the *Yorktown*, the horse-powers were not corrected for indicator error, as was subsequently done. This, however, is of less importance, as the screws of the older vessels were much larger than would now be designed.

The speeds of some of the vessels, which were tried for horse-power only, are not entirely reliable, owing to the fact that, on the trial, they were determined by patent log and bearings with an estimate of the tide. The values given in the table for these cases have been adopted after comparison with similar ships where the speed was accurately determined, taking into consideration the circumstances of wind and weather, engine revolutions, &c. As the table is not constructed to support any theory, these computed values are believed to be entitled to nearly as much weight as those obtained by direct observation.

The illustrations are reductions of accurate copies of the working drawings, permission having been kindly granted by Engineer-in-Chief Melville.

Most of the records are the results of trials for four or more hours at full power, but, where the data for shorter periods were more carefully determined, they have been used. This is the case with the *Boston*, *Chicago* and *Yorktown*, where the results of measured-mile performances are given, and the *Vesuvius*, whose horse power was only determined for a short run. The speeds are in knots of 6,080 feet. The indicated thrust is computed from the ordinary formula.

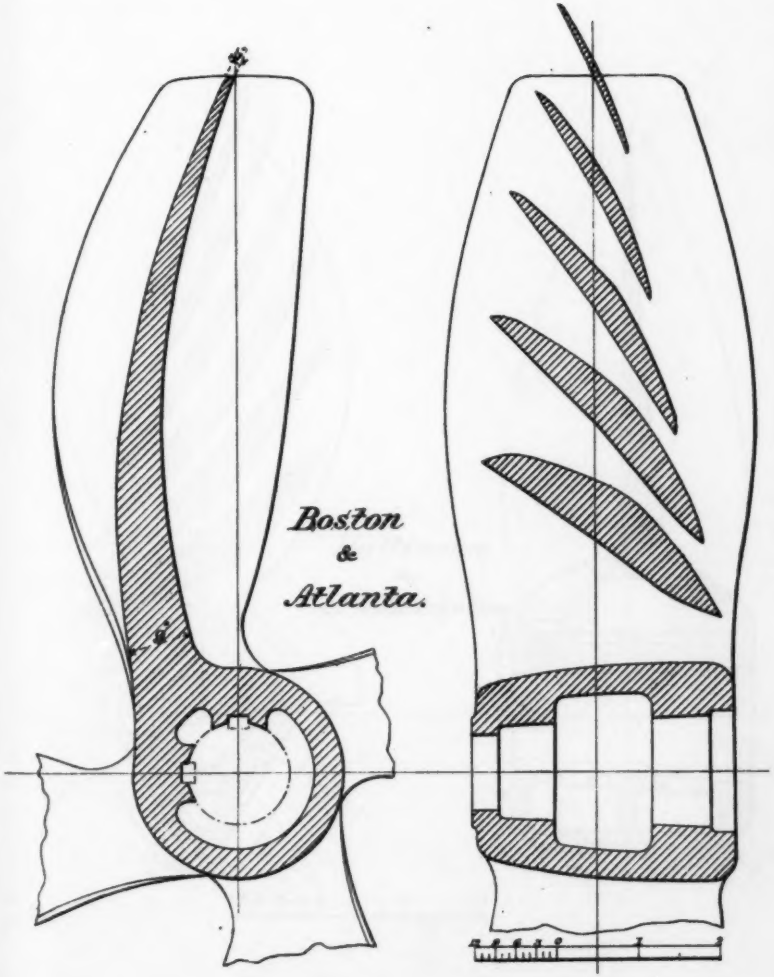
$$T = \frac{I.H.P. \times 33{,}000}{P \times R}$$

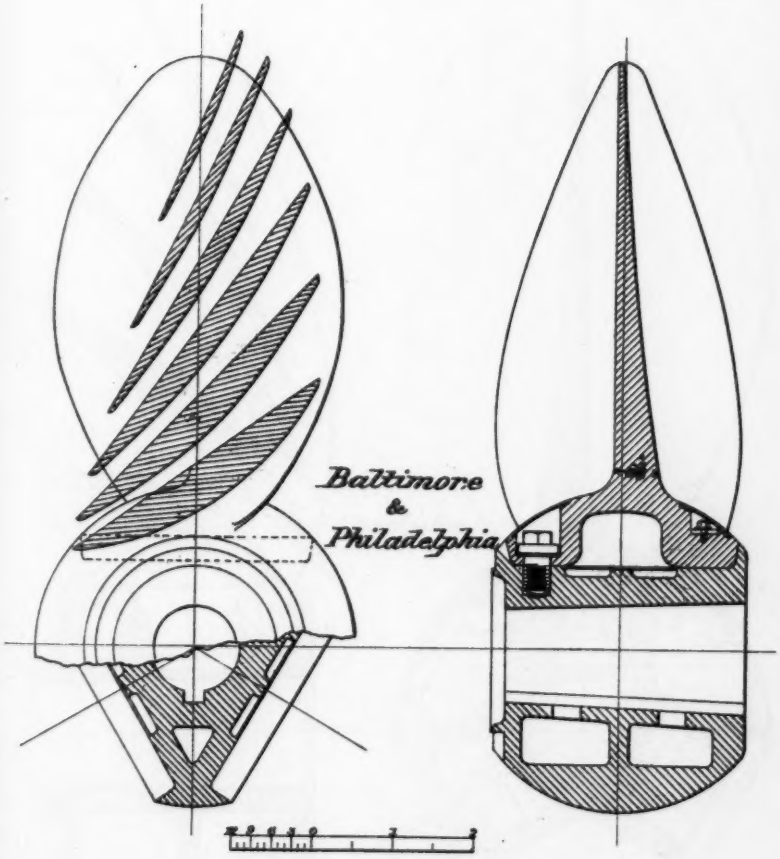
where

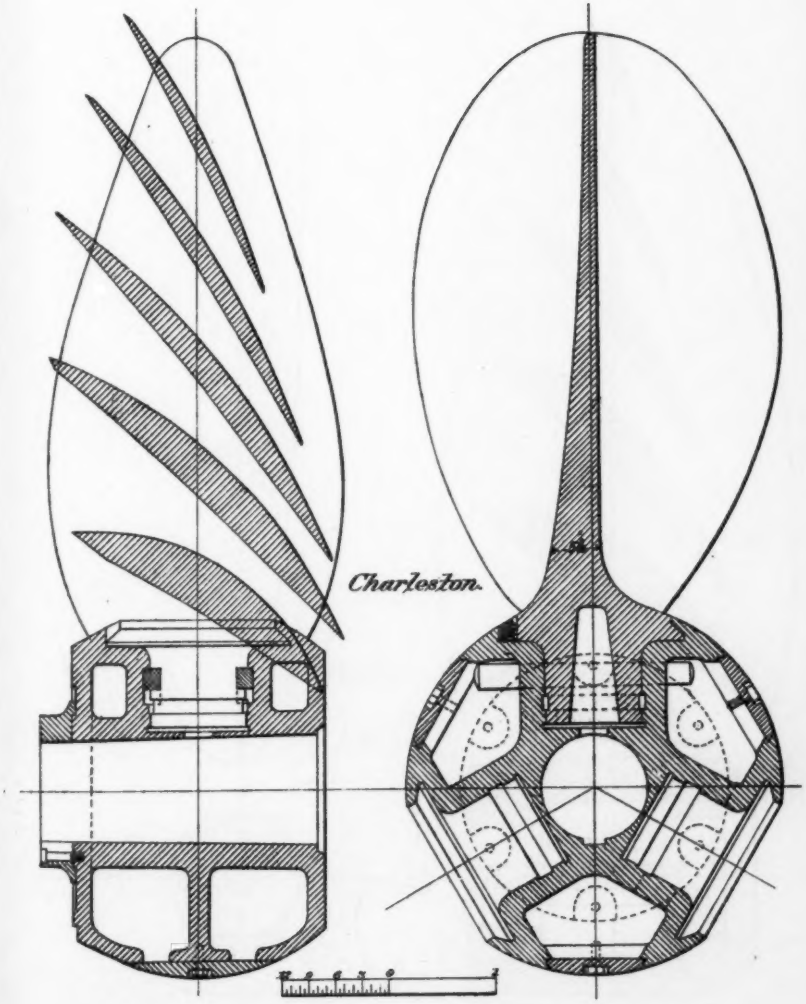
$I.H.P.$ = Indicated horse power of main engines only.
R = revolutions of propeller per minute.
P = mean pitch of propeller in feet.

In the case of twin screws, the indicated thrust is the mean for the two screws.

Two performances of the *Baltimore* are given, because there was a decided change in the pitch and horse power, and, in connection with the tables of engine dimensions and trial data in Volume III of the JOURNAL, they enable the effect of change of pitch to be studied. As this change was made by simply shifting the blades slightly on the bosses, all other propeller data are the same for both cases.


Boston
&
Atlanta.


Baltimore
&
Philadelphia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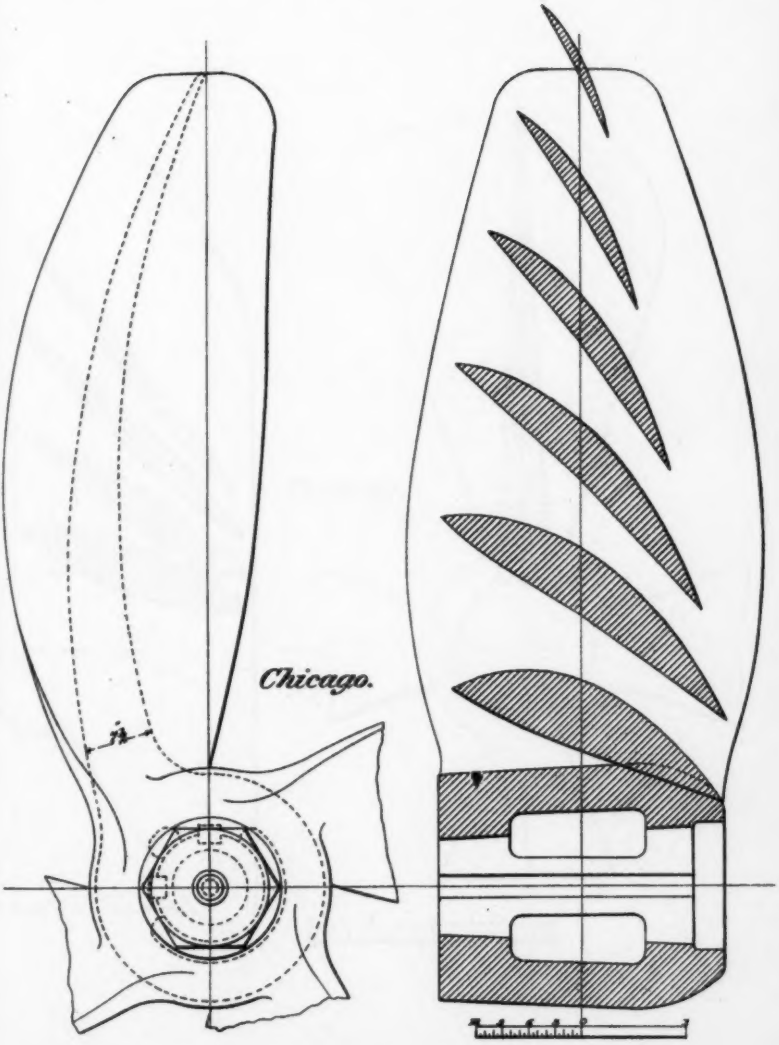
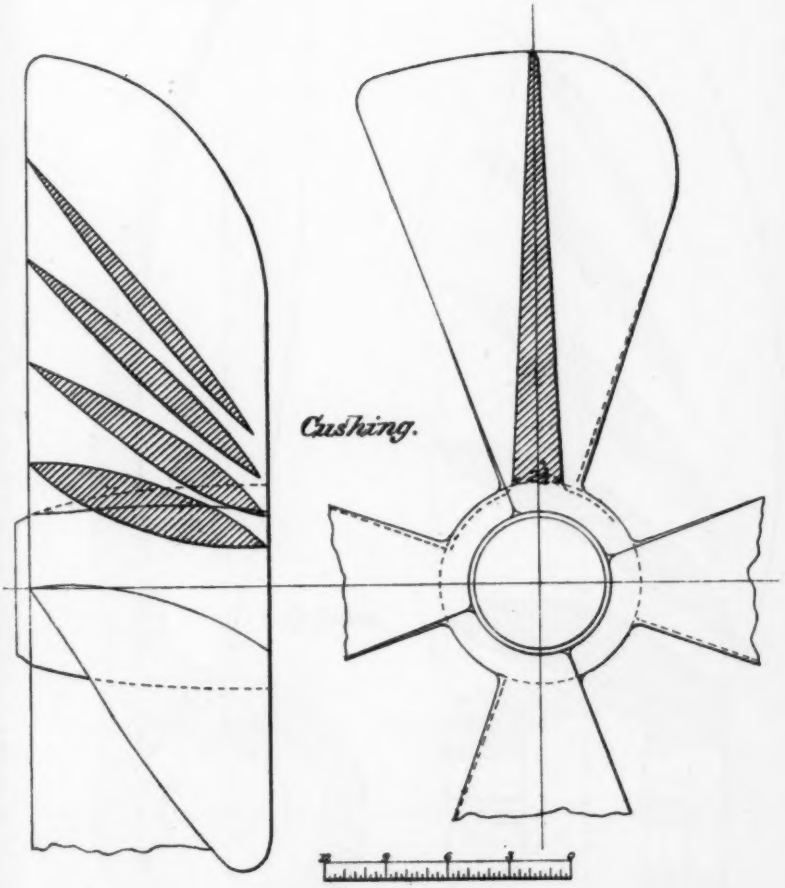
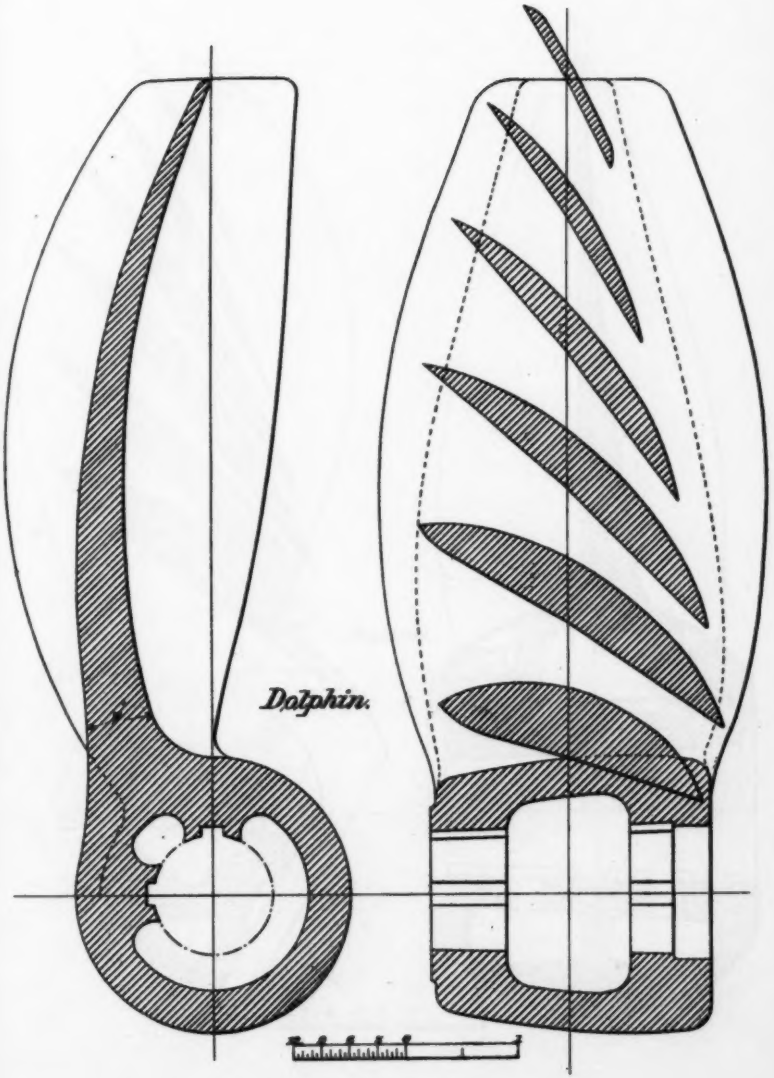
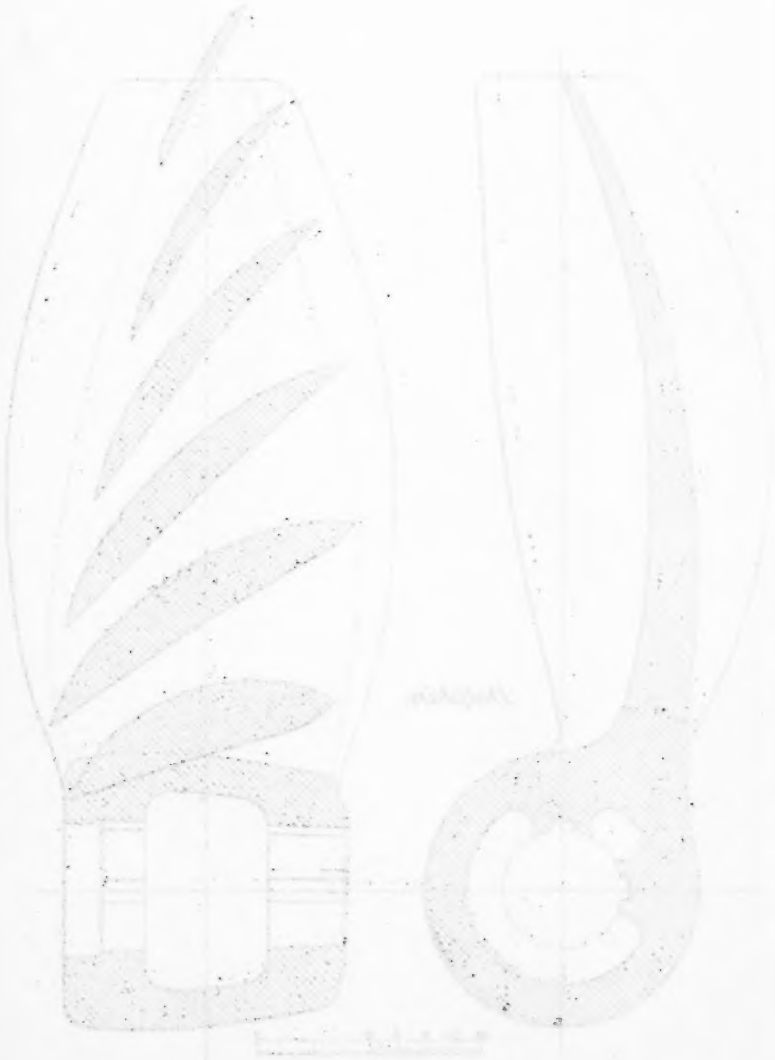
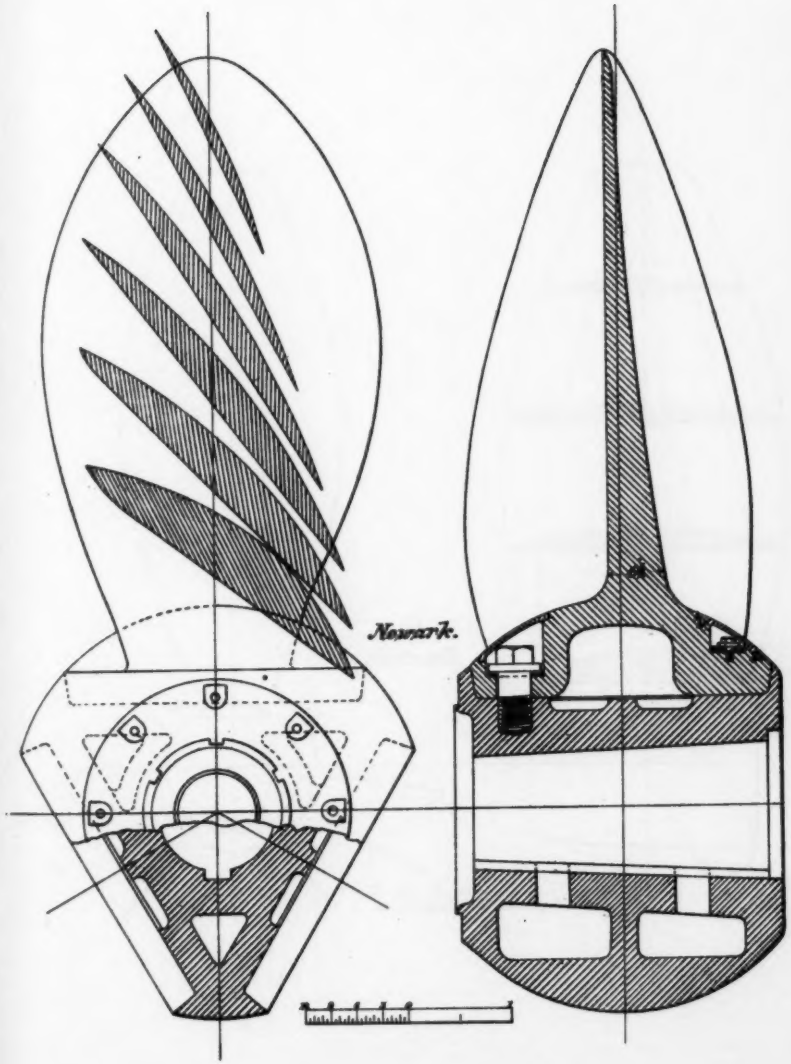

Chicago.


Cushing.



Dolphin.

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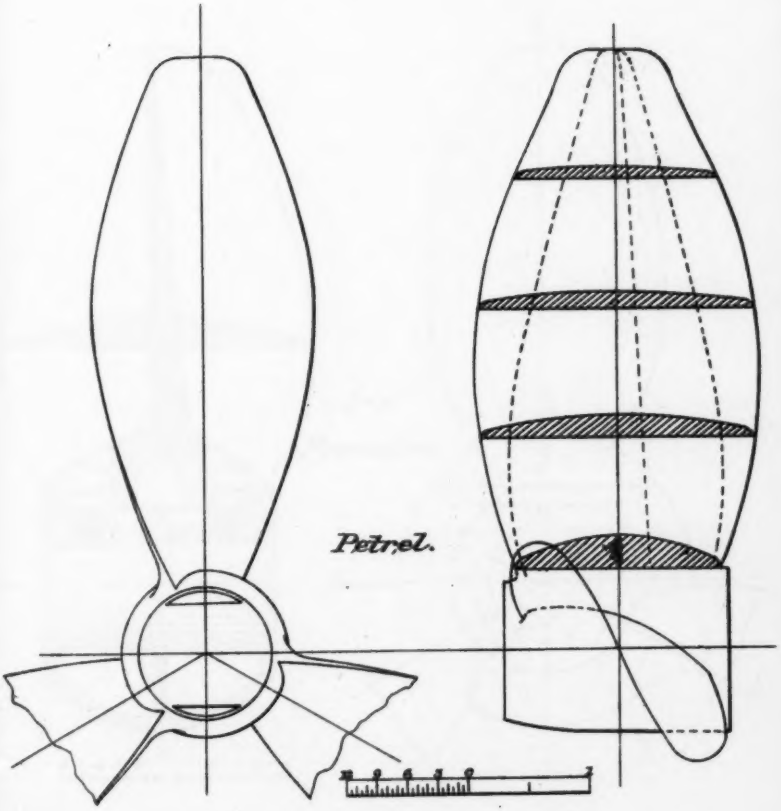
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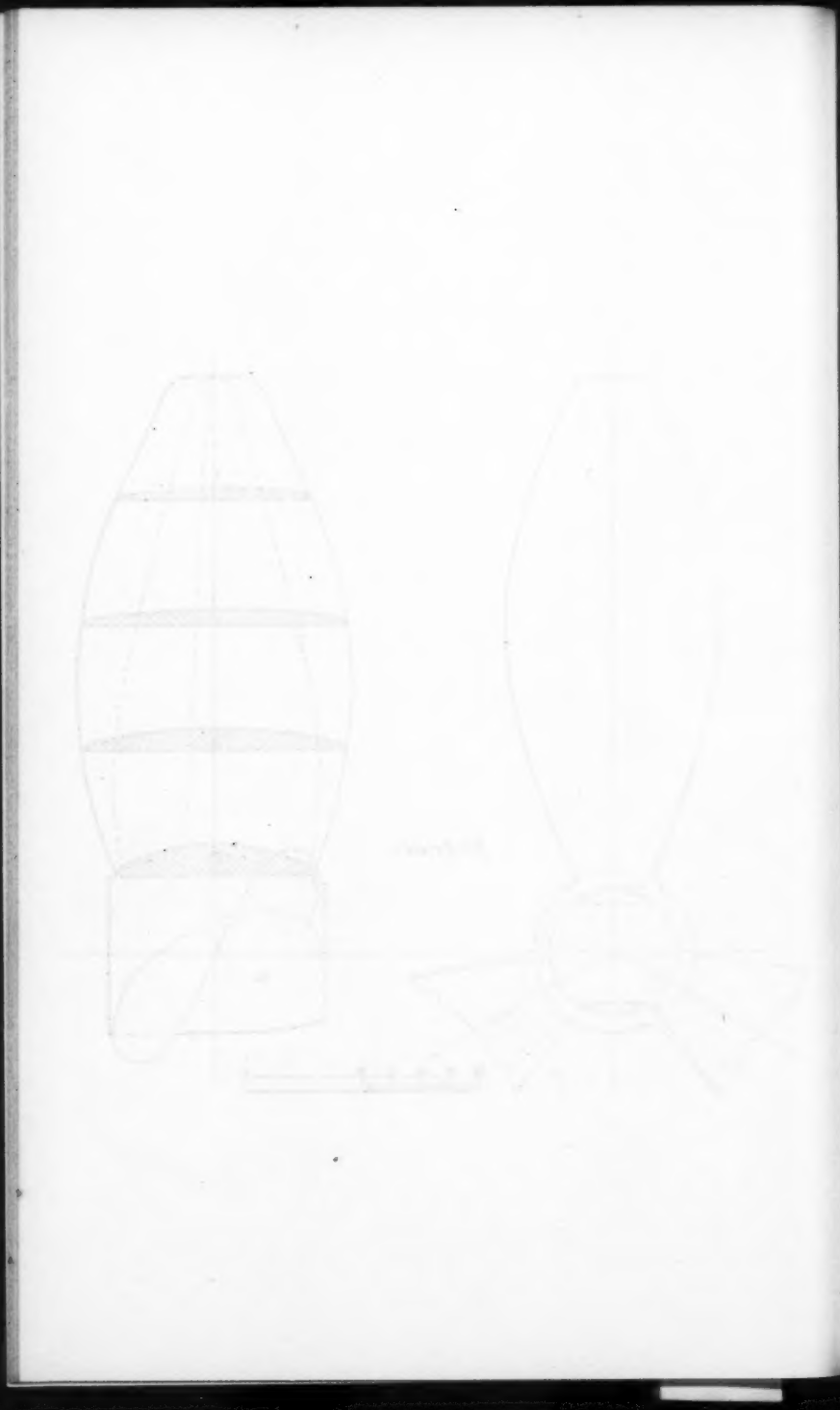
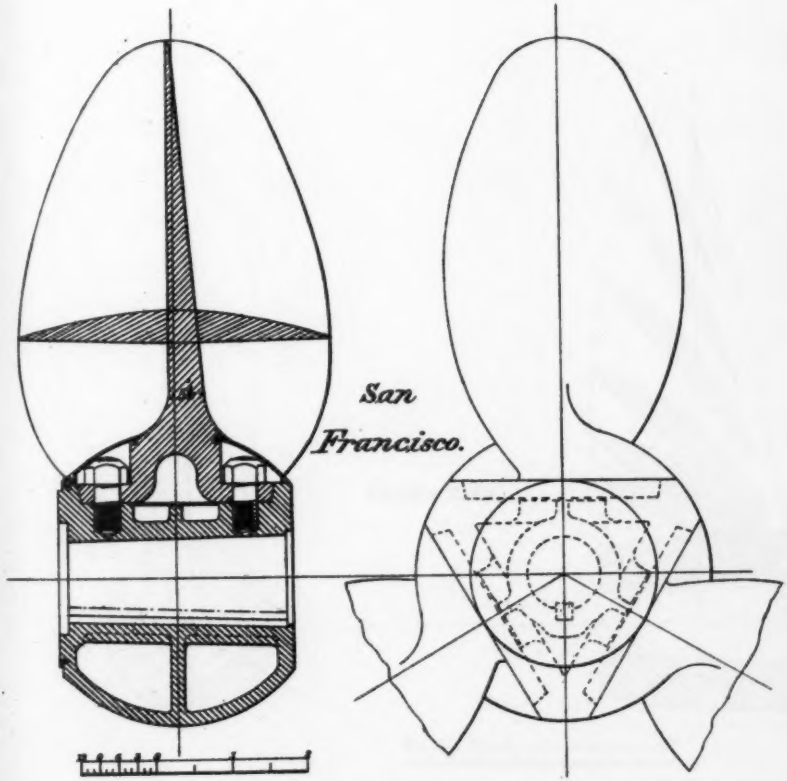
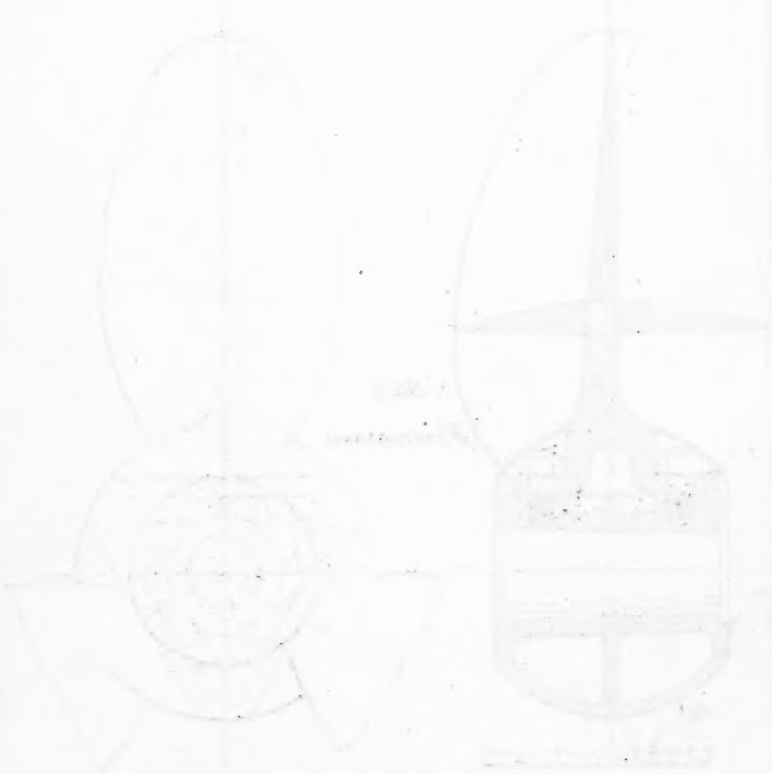
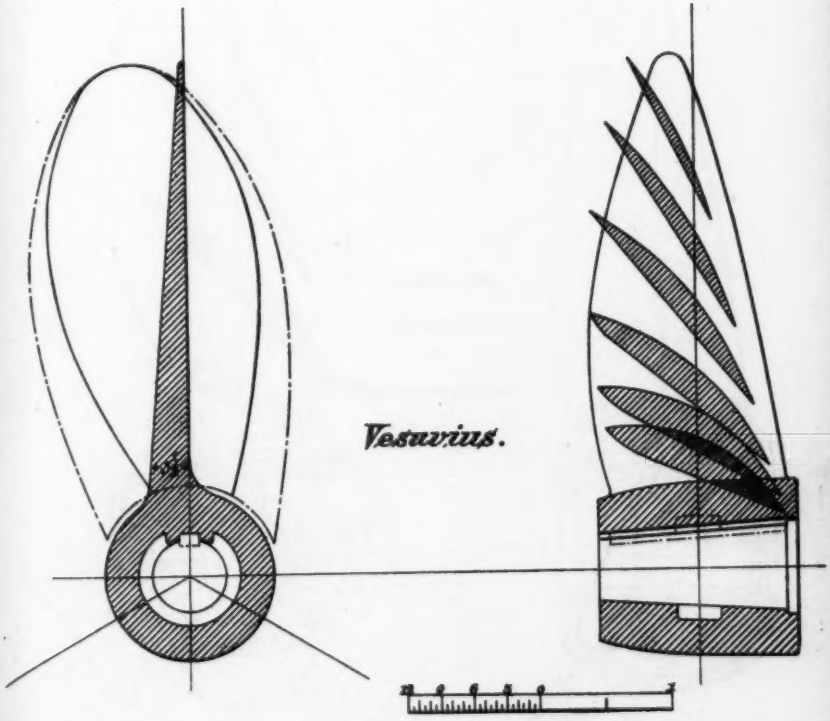
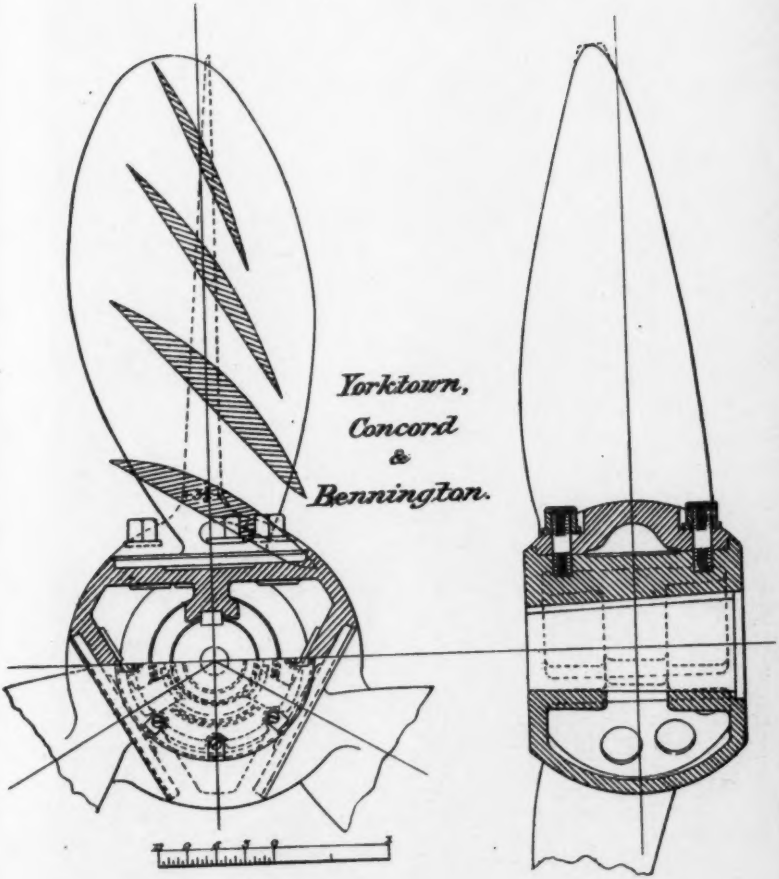



San
Francisco.





Vesuvius.


Yorktown,
Concord
&
Bennington.

		Atlanta.	
1	Number of propellers,	1	2
2	Number of blades to each propeller,	4	3
3	Diameter of propeller in feet,	17.0	14
4	Mean pitch of propeller in feet,	24.28	20
5	Helicoidal area of each propeller in square feet,	96.15	57
6	Material of which propeller is made,	Cast iron.	M
7	Type of propeller,	Hirsch.	H
8	Draught of water aft on trial in feet,	19.25	21
9	Distance from bottom line of keel to axis of propeller in feet,	9.2	10
10	Immersion of axis of propeller in feet,	10.05	11
11	Revolutions of engines per minute,	72.05	118
12	Speed of ship in knots per hour,	15.5	19
13	Slip of propeller in per cent. of its own speed,	10.22	16
14	I.H.P. developed by main engines,	2993.42	8678
15	Indicated thrust per square foot of helicoidal area,	587.3	1060
16	Aggregate mean effective pressure on L.P. pistons,	22.94	25
17	Diameter of L.P. cylinder in inches, and stroke in feet,	(2) 74; 3.5	94; 3
18	Length of vessel between perpendiculars in feet,	270.25	315
19	Beam of vessel on load-water line in feet,	42.15	48
20	Mean draught on trial in feet,	17.0	19
21	Displacement at this draught in tons,	3025	4391
22	Immersed midship section in square feet,	635	816
23	Coefficient of fineness (prismatic),	.547	

AND PERFORMANCE OF SCREW PROPELLERS IN USE ON VESSELS OF THE U

Baltimore.		*Bennington.*	*Boston.*	*Charleston.*	*Chicago.*	*Concord.*	*Cushin*
2	2	2	1	2	2	2	2
3	3	3	4	3	4	3	4
14.5	14.5	10.5	17.0	14.0	15 5	10.5	4
20.0	21.5	13.71	23.67	17.5	24 59	13 20	8
57.17	57.17	24.31	95.67	54 75	77.93	26.52	9
Manganese bronze.		Manganese bronze.	Cast iron.	Manganese bronze.	Cast iron.	Manganese bronze.	Mangan bronz
Modified Griffith.		Mod. Griffith.	Hirsch.	Mod. Griffith.	Hirsch.	Mod. Griffith.	Mod. Gri
21.58	21.58	15.17	19.7	19.11	21.60	15.58	4
10.5	10.5	6.0	9 2	8.73	8.90	6.0	2
11.08	11.08	9.17	10.5	10.38	12.70	9.58	2
18.05	116.25	150.9	72.2	114.65	70.35	152.4	37
19.57	19.84	17.5	15.58	18.20	15.33	17.0	2
16.01	19.57	14.32	7.62	8.08	10.20	14.37	2
78.29	9831.07	3332.80	3854.82	6316.06	4541.84	3314.30	175
60.8	1135.3	1089.6	778.0	948.75	555.9	1025.2	99
25.07	28.84	37.09	29.47	26.18	23.57	36.65	3
; 3.5	94 ; 3.5	50 ; 2.5	(2) 74 ; 3.5	85 ; 3.0	78 ; 4.75	50 ; 2.5	(2) 22½ ;
15	315	228	270.25	300	315	228	13
48.5	48.5	36	42.15	46	48.21	36	1
19.52	19.87	14	17.67	17.87	19.0	14.01	
91.5	4500	1706	3235	3580	4543	1707	10
16.64	833.0	435.6	670	716	796	436	4
.515	.515	.520	.546	.510	.551	.520	

[a] Measurement from line of keel prolonged.

ANCE OF SCREW PROPELLERS IN USE ON VESSELS OF THE UNITED S

	Bennington.	*Boston.*	*Charleston.*	*Chicago.*	*Concord.*	*Cushing.*	*Do*
	2	1	2	2	2	2	
	3	4	3	4	3	4	
	10.5	17.0	14.0	15 5	10.5	4.25	1
	13.71	23.67	17.5	24 59	13 20	8.42	2
	24.31	95.67	54 75	77.93	26 52	9.30	7
	Manganese bronze.	Cast iron.	Manganese bronze.	Cast iron.	Manganese bronze.	Manganese bronze.	Cas
	Mod. Griffith.	Hirsch.	Mod. Griffith.	Hirsch.	Mod. Griffith.	Mod. Griffith.	Hi
	15.17	19.7	19.11	21.60	15.58	4.92	1
	6.0	9 2	8.73	8.90	6.0	2.05[a]	
	9.17	10.5	10.38	12.70	9.58	2.87	
	150.9	72.2	114.65	70.35	152.4	372.12	7
	17.5	15.58	18.20	15.33	17.0	22.48	1
	14.32	7.62	8.08	10.20	14.37	27.3	1
	3332.80	3854.82	6316.06	4541.84	3314.30	1754.45	214
	1089.6	778.0	948.75	555.9	1025.2	993 4	56
	37.09	29.47	26.18	23.57	36.65	39.29	2
	50; 2.5	(2) 74; 3.5	85; 3.0	78; 4.75	50; 2.5	(2) 22½; 1.25	78;
	228	270.25	300	315	228	138	24
	36	42.15	46	48.21	36	14.25	3
	14	17.67	17.87	19.0	14.01	4.87	1
	1706	3235	3580	4543	1707	105.3	141
	435.6	670	716	796	436	47.68	33
	.520	.546	.510	.551	.520	.384	

[a] Measurement from line of keel prolonged.

Dolphin.	*Newark.*	*Petrel.*	*Philadelphia.*	*San Francisco.*	*Vesuvius.*	*Yorktown.*	
1	2	1	2	2	2	2	1
4	3	3	3	3	3	3	2
13.75	14.5	9.75	14.5	13.5	7.75	10.5	3
24.08	18.98	12.25	20.39	18.75	9.37	12.5	4
70.72	52.78	23.6	57.17	57.59	15.9	25.42	5
Cast iron.	Manganese bronze.	Aluminum bronze.	Manganese bronze.	Manganese bronze.	Manganese bronze.	Manganese bronze.	6
Hirsch.	Mod. Griffith.	Mod. Griffith.	Mod. Griffith.	Mod. Griffith.	Mod. Griffith.	Mod. Griffith.	7
15.42	20.60	11.54	21.58	20.42	9.58	15.06	8
7.8	9.10[a]	5.50	10.20	11.00[a]	3.33	6.00	9
7.62	11.50	6.04	11.38	9.42	6.25	9.06	10
74.15	127.0	126.78	119.57	124.81	268.89	160.80	11
15.5	19.0	11.79	19.68	19.52	21.42	16.65	12
12.03	20.13	23.07	18.20	15.48	13.85	16.06	13
144.17	8582.30	1050 57	8533.18	9580.72	3711.86	3415.73	14
560.35	1113.35	946.0	1010.2	1173.05	1528.85	1103.2	15
25.11	37.02	30.07	30.55	30.51	37.76	35.80	16
3; 4.0	76; 3.33	46; 2.75	86; 3.33	94; 3.0	(2) 34; 1.67	50; 2.5	17
240	310.83	175	315	310	246.25	228	18
32	49.17	31	48.57	49.14	26.42	36	19
13.79	18.27	11.21	19.21	18.75	9.51	13.84	20
413	3980	855	4325	4088	771	1680	21
338	775	286	815	770	192	432	22
.501	.499	.490	.515	.501	.433	.518	23

VII.

METHOD OF MOULDING A CYLINDER IN DRY SAND AT THE BATH IRON WORKS.

By Assistant Engineer S. H. Leonard, U. S. Navy.

Large steam cylinders are cast either in a dry sand or a loam mould. If by the former method, which is usually the case when they are more or less complicated and there are two or more to be made of the same size, a complete pattern is made and rammed up in dry sand in a flask. In the case of a loam mould, patterns are also required of the steam chest, steam and exhaust nozzles, and all brackets, webs, lugs, bosses, etc.; these are built into the loam work as the cylinder is swept up. The following description refers to the intermediate cylinder for the *Harbor Defence Ram.* This cylinder is 36 inches in diameter by 36 inches stroke, and is designed for a liner 1 inch thick.

The work on the cylinder proper forming so small a proportion of the total required on the mould, there was relatively little that could be swept up, and consequently time and expense were saved by making a complete pattern and moulding in dry sand. There were two of these cylinders, so that one pattern answered for both.

The pattern was made of well-seasoned clear white pine. Such wood warps very little, is not likely to check or split, is light to handle, has a fine grain and is easily worked. A two-foot shrinkage rule was used, measuring $24\frac{9}{32}$ inches; or, in other words, a shrinkage of $\frac{9}{32}$ of an inch was allowed in two feet.

In making the pattern, the barrel or cylinder proper was built up as follows: To three ring discs about 3 inches thick and 4 inches wide, one at either end and one in the center of the cylinder, are screwed longitudinal strips $\frac{3}{4}$-inch thick and 5 inches wide, which are firmly glued to each other; secured to these

discs at either end are four additional circular discs, each about 1¼ inches thick. At the stuffing-box end of the cylinder the four discs have a diameter equal to that of the *outside* of the cylinder, and after gluing together are turned out to the dished form called for in the drawing. The stuffing box is let slightly into this head and its webs located per drawing.

The lower discs are of the same diameter as the cylinder *inside the longitudinal strips*. The cylinder's lower flange is made up of circular strips, breaking joint, firmly glued to each other and then turned to size, its internal diameter being the same as that of the lower discs over which it is slipped, leaving about 2 inches of the disc projecting, which forms the cylinder core print.

The steam chest is made in the same general manner in five separate box sections, two steam ports and three cylindrical sections of steam chest. The cylinder and steam chest are each provided with axial holes for the insertion of iron rods for the purpose of drawing them from the sand. The steam ports, steam chest, lugs, bosses, stuffing box and its webs, brackets and cylinder flange, are all fitted to the barrel of the cylinder with wooden pins; these are removed—where necessary in drawing the pattern—as the mould is built up.

The pattern when complete receives a coating composed of lamp black, shellac and alcohol, which gives it a smooth, glossy surface, filling the pores of the wood and preventing the absorption of moisture. In order to prevent any chance of mistaking a boss or projection for a core print, the latter receive a coat of shellac only, which leaves them a bright straw color.

The pattern maker, after finishing the cylinder, turns his attention to the necessary core boxes and sweeps. These are made as simply as possible, often consisting of only a skeleton frame, as is well illustrated in the sketch of the frame for the steam-port cores, Plate 3, Fig. 8. This consists of three distinct parts; the circular portion *A*, consisting of strips of wood glued together, and to which are secured the side pieces *B;* the reverse curve piece *C*, made up as shown; and the skeleton piece *D*, screwed to the top of *A*, and which carries a small section of the steam chest *E*. Fig. 3 shows the construction of the core

box for the exhaust nozzle, one-half of the core being formed at a time, and the two halves joined, after baking, with a thick flour paste. The same construction is used for the steam nozzles, Fig. 5.

The frame for the cylinder core is made up of circular strips, as shown in Fig. 9; it is 6 inches deep, and is made up in sections, as shown in Plate 2, Fig. 2. The frames for the steam-chest cores, Fig. 6, are made in a similar manner in two rings corresponding to the two diameters of core; they are fitted to each other by a small lip turned on the edge of the upper ring; when ramming up, the frames are held together by means of several staples driven into their outer surfaces. The core boxes are all made of the same material as the pattern, and receive the same black coating on their internal surfaces. The sweeps, Figs. 2 and 9, are simply wooden strips cut to the proper shape from dimensions taken from the drawing, and in use are secured to a central iron spindle as an axis, about which they are worked; their bearing edges are beveled for the purpose of leaving the sand freely in sweeping.

The pattern being now ready for the foundry, the first work in the latter is the casting and fitting of the flask, which in this case consisted of eight sections, five of which were 7 inches and three 12 inches deep, all being 8 feet 10 inches long by 6 feet broad outside. The same flask was used for the H.P. and I.P. cylinders and also the same sides for the L.P. cylinder, new ends (longer) only being required in the latter case. These flask sections were cast from a pattern in green sand. A base plate $1\frac{1}{2}$ inches thick and of the same dimensions as the flask is cast in the open sand without a pattern, its outline being marked off with the aid of a straightedge on a prepared body of sand on the foundry floor; a strip of wood 4 or 5 inches wide and about 2 feet long, with a thickness slightly greater than that of the plate, is used for tamping the sand against, the strip being gradually worked along the line until the mould is complete.

A pit about $2\frac{1}{2}$ feet deep is now dug in the foundry floor, into which three cast-iron resting bars, 4 inches $\times$ 5 inches, are lowered and adjusted with a spirit level. Upon these the base plate

is placed, which in turn forms the support for the lower flask as shown in Plate 1, Fig. 2. The lower flask is rammed up with *green* sand and then scraped off with a straightedge to about 2 inches below the top of the flask. The barrel of the cylinder is now placed in its proper position in the flask and the pattern made complete by pinning on the steam chest, nozzles, legs, etc., the whole pattern resting on the core prints of the cylinder and steam chest. The lower flanges are held in place and the whole nicely adjusted by wooden wedges placed under these flanges. The pattern is now given a coating of light machine oil applied with a cloth or bunch of waste for the purpose of preventing the sand from adhering to the pattern, as well as to constitute an additional safeguard against the absorption of moisture from the damp sand. The remainder of the lower flask is rammed up with *dry* sand which is carefully tamped under the cylinder and steam-chest flanges, lower bracket and steam nozzle, the wedges being removed as the work goes on. The sand in this flask is built up to the level of the top of the lower flange of the cylinder. In ramming up, each section of flask acts as a partial cope to the one immediately below it, and therefore the parting surface must be so made that each flask may be raised in turn without breaking the mould. The line of each flask joint is shown by heavy dotted lines in Plate 1, Fig. 2.

The dry (facing) sand is mixed as follows:

6 pails new loam sand.
6 pails beach sand.
1 pail flour.
1½ pails clay water.
½ pint molasses.

Parting sand is now sprinkled over the lower flask and the second section is lowered into position. The next operation is to fit thin cast-iron brackets to the sides of the flask to form a support to the sand. These brackets are cast in the open sand and along their lower edges nails are cast in, Plate 2, Fig. 1. They are spaced about 6½ inches apart and are secured with ½-inch bolts passing through the vent holes in the sides of the flask; they are slightly less in width than the depth of flask

section to which they are fitted, and are of varying lengths reaching to within about an inch of the pattern; they are cast with several holes about 2 inches in diameter for the purpose of locking them in the sand and also to reduce their weight; these brackets all receive a coat of clay wash to ensure the sand adhering to them. Facing sand, mixed as above described, is now shoveled in the flask and carefully rammed in all around the pattern, and to about an inch in depth all over the bottom of the flask. To give additional strength to the sand, cast-iron gaggers $\frac{1}{4}$ inch square in section, with legs about 3 inches and 6 inches long respectively, are bedded in the sand alongside the brackets, after receiving a coat of clay wash; gaggers about 10 inches long are bedded horizontally. These gaggers are worked in as the flask is rammed up, facing sand being used to a thickness of about 2 inches around the pattern, and foundry or green sand filling in the intervening space to the sides of the flask. This sand is made a little more open than ordinary green sand by the addition of fine gravel, and to maintain its strength it is dampened with a thin clay water. The upper portion of the flask to about an inch in depth is rammed wholly with facing sand, over which, after sleeking, is strewn the parting sand. As stated above, the pins securing the bosses, brackets, etc., are removed as these parts become securely bedded.

The successive flask sections are rammed up in the same general manner as described. In some of the sections, however, the pattern falls away considerably from the sides of the flask, in which case, to give sufficient support to the large body of sand, extra sides are bolted between the flask ends, brackets being bolted to these in turn as well as to the outer sides; this is shown in Plate 2, Fig. 1, which is a section of the mould with the fourth flask in place ready for ramming, the pattern being removed and the cores in position.

The body of sand between the steam chest and the cylinder is supported by four $\frac{5}{8}$-inch round iron rods—two in each flask—bolted to the side plates; to these rods gaggers are wired as shown. This body of sand is side-vented with the vent wire. It is of course understood that the sand around the *cylinder* is

supported in the same manner by nails, gaggers, etc., as about the steam chest, although not filled out in the drawing. In making up the cope, cross plates are bolted to the flask sides and the sand firmly rammed between them, the gate sticks—1½ inches by ½ inch—also vent and riser plugs, being previously placed in position. In order to properly ram the sand under the brackets *G*, *H*, *K*, Plate 1, Fig. 1, square pieces are cut out of the pattern as shown at *H*, and after the ramming are replaced. These pockets of sand are also side-vented with the vent wire. To give support to the hanging sand between the webs surrounding the stuffing box, thin bracket plates are suspended by wiring from the heavy cross-plates, and alongside these latter, all through the cope, are imbedded numerous gaggers, brackets, nails and wires. The upper surface of the cope does not receive a layer of *dry sand*, as is the case with the other flask sections; unlike the other sections, also, it is well top-vented with a light vent wire.

The following portions of the pattern remain in the cope upon its being raised: the stuffing box and webs, the cross-head slide bracket, steam-chest core print, the upper half of steam nozzle, and the top sections of upper steam port; the two latter are held in place by means of wires secured to them, passing through to the top of the cope where they are secured.

The cope is now swung by the crane to an available place in the foundry floor and turned bottom up. The sharp corners of sand are trimmed off with a trowel, and nails impressed where necessary to give additional strength. The different pieces of the pattern are now carefully drawn, the mould sleeked and given a coat of black wash. The stuffing-box flange is detachable and is cut obliquely in order that it may be drawn after removing the stuffing box proper. The cylinder proper, with its two side brackets, *M*, *N*, is now drawn from the sand by the aid of an eye-bolt screwed into an iron plate secured to the lower discs; the lower flange is left in the mould. The upper section of the steam chest, lower half of steam nozzle, and the cylinder legs, are now drawn; also the several bosses which were at-

PLATE I

FIG. 1

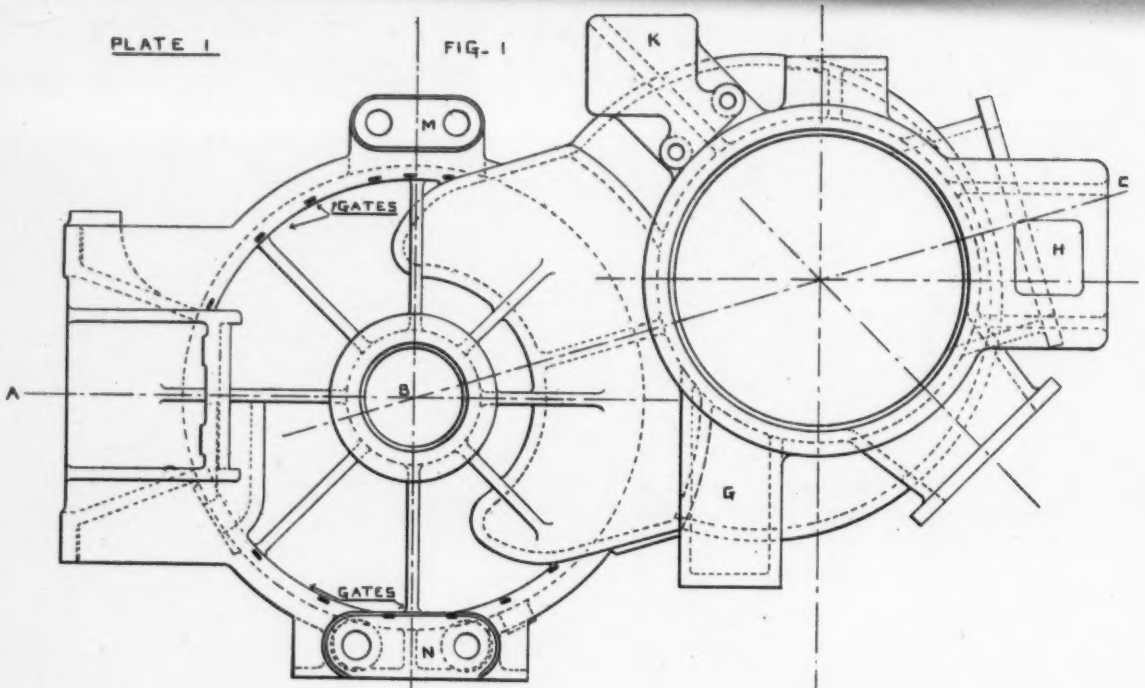
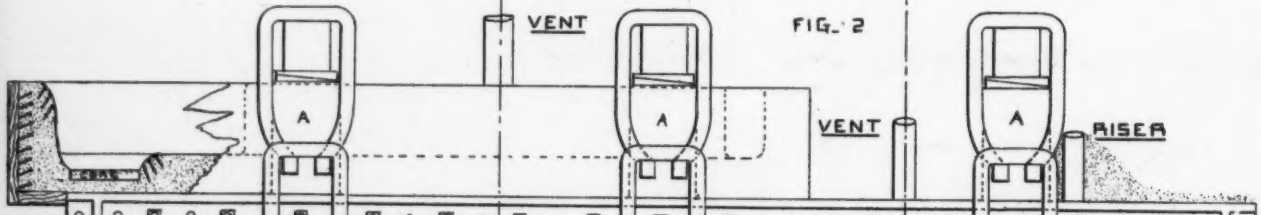


FIG. 2



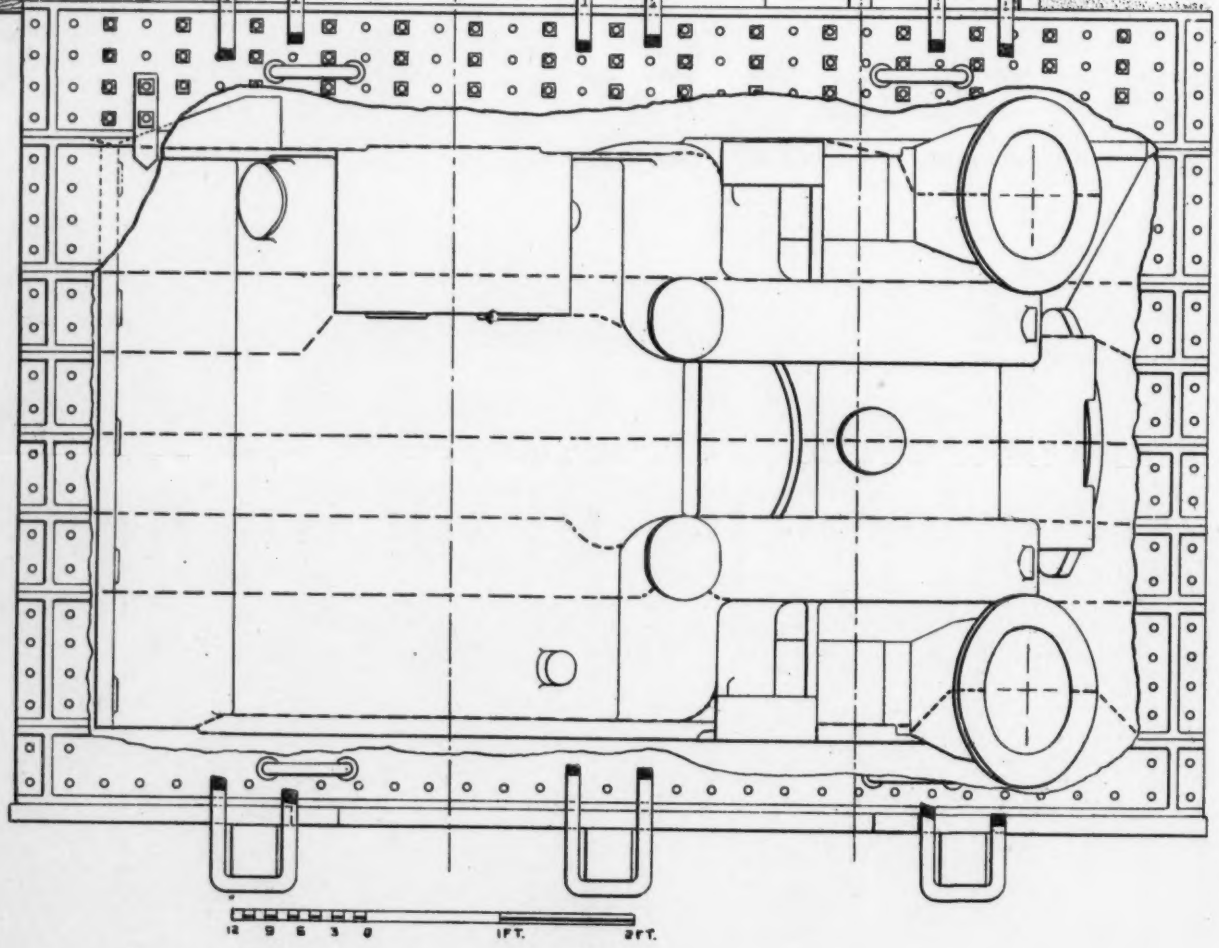
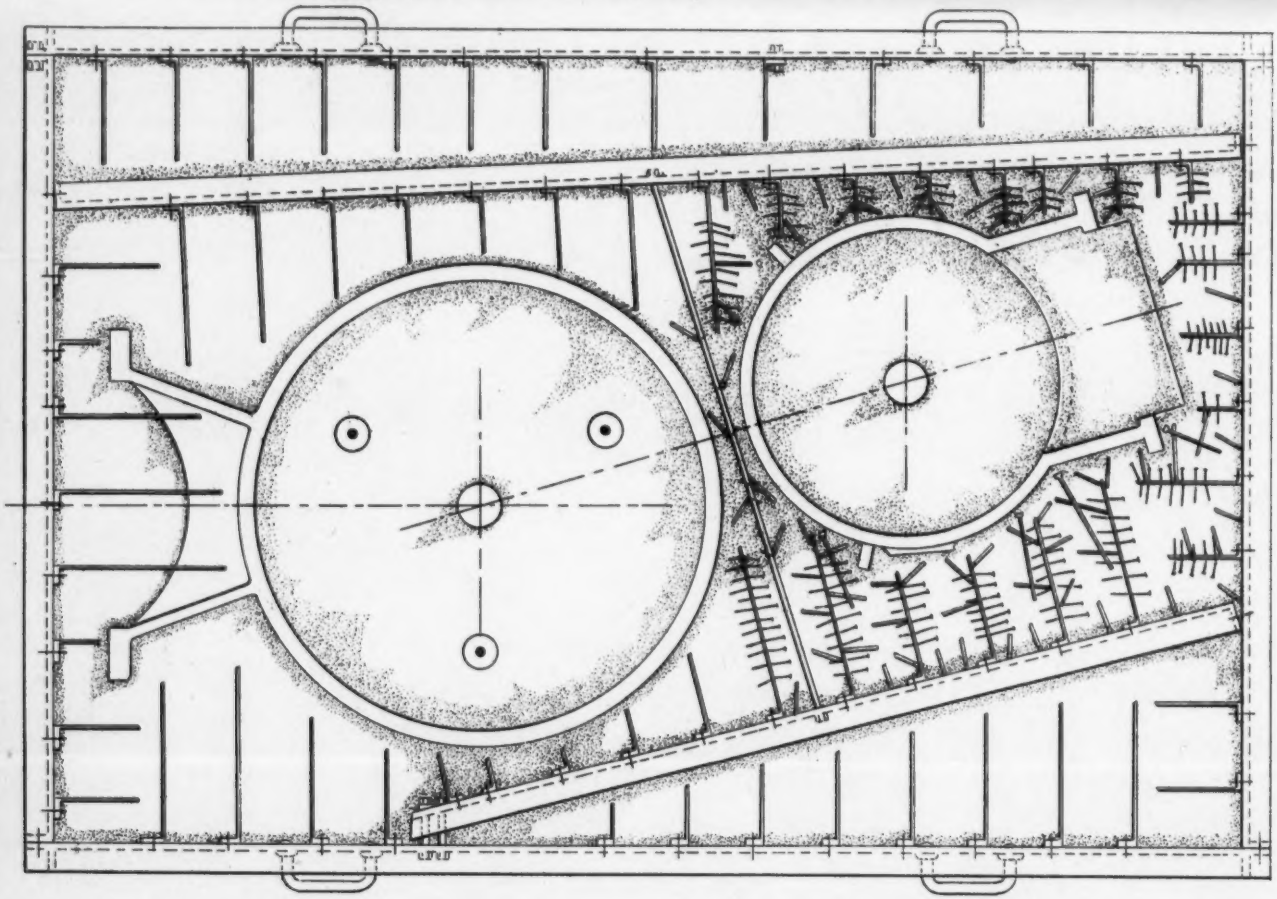
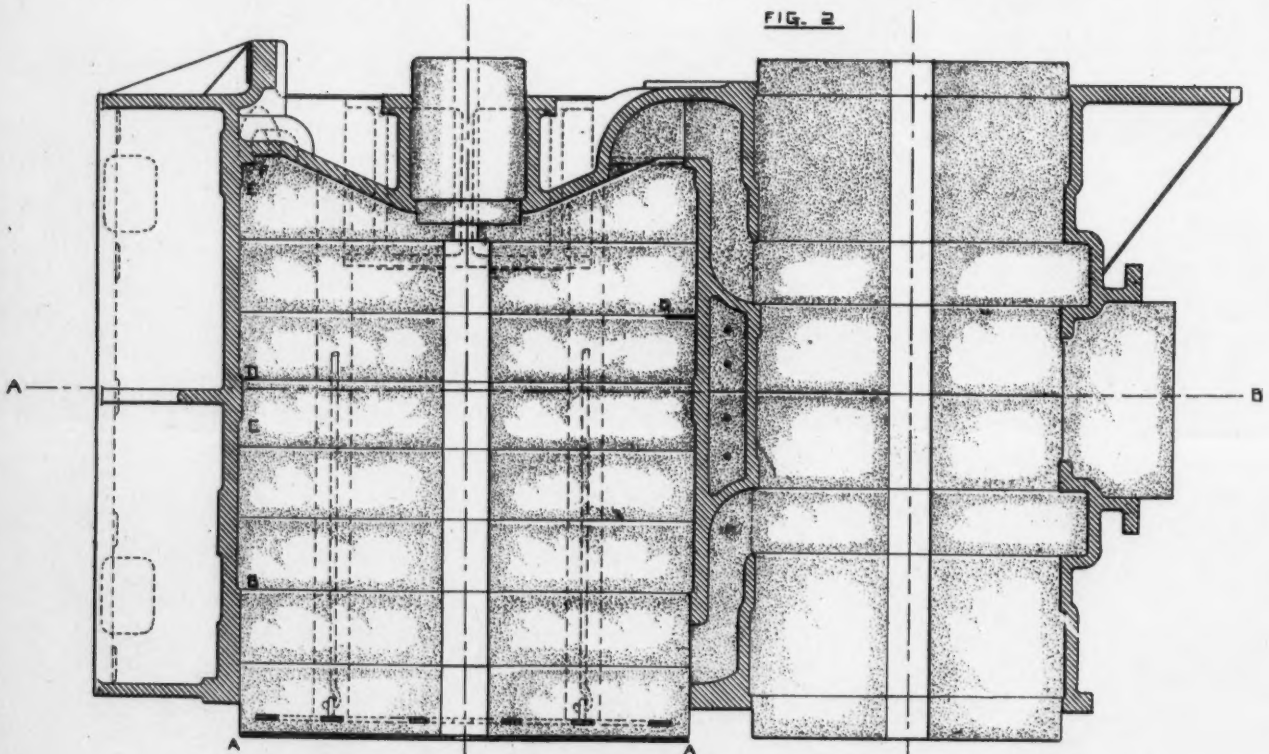

12 9 6 3 0
1FT.
2FT.

PLATE 2 FIG. 1



SECTION ON LINE A-B WITH 4TH FLASK IN POSITION

FIG. 2



SECTION ON LINE A-B-C PLATE I

12 9 6 3 0 1FT. 2FT.

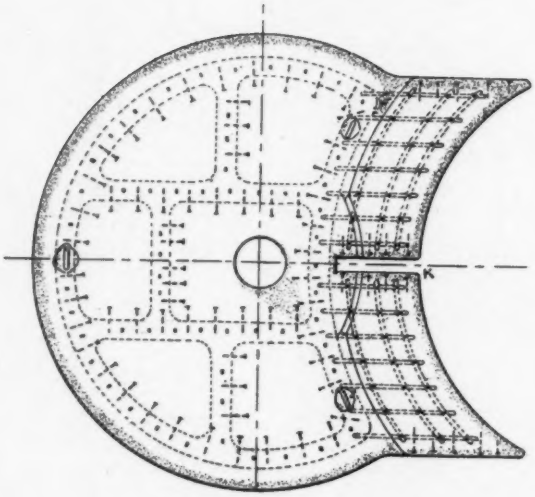
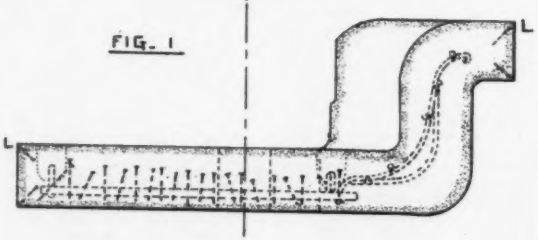


FIG. 1



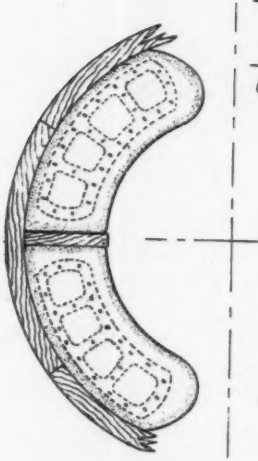
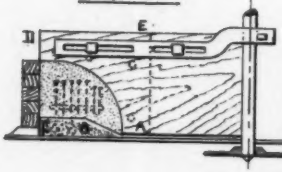


FIG. 2



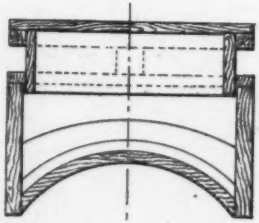
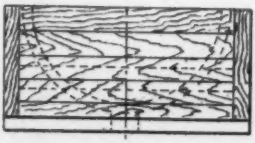


FIG. 3



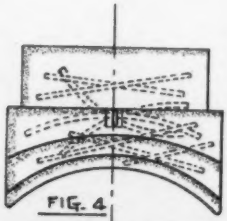


FIG. 4

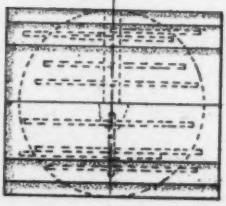


FIG.

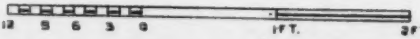


PLATE 3

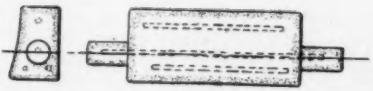


FIG. 7

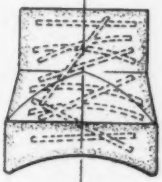
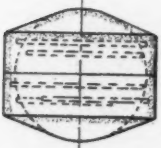
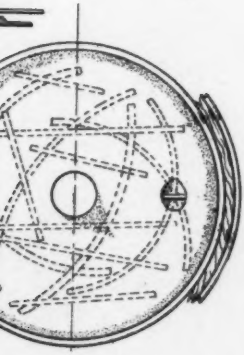
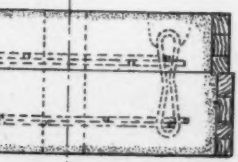


FIG. 5





r. 6



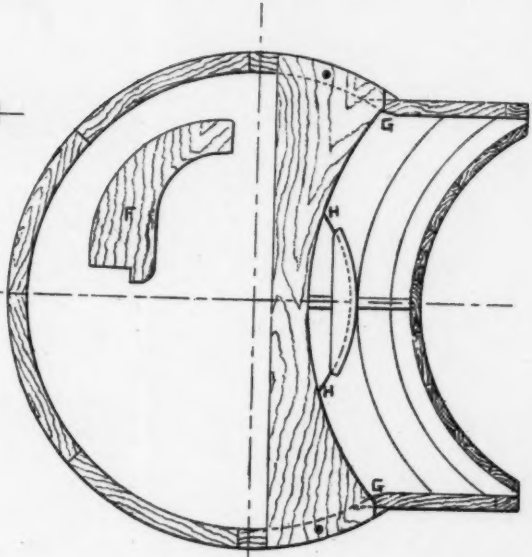
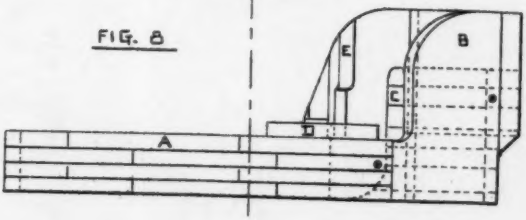


FIG. 8



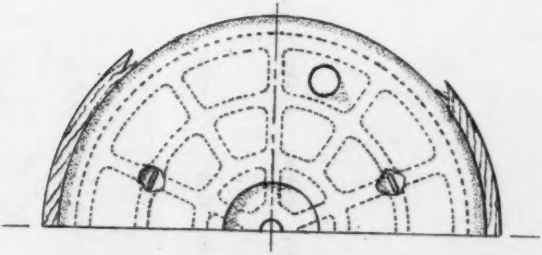
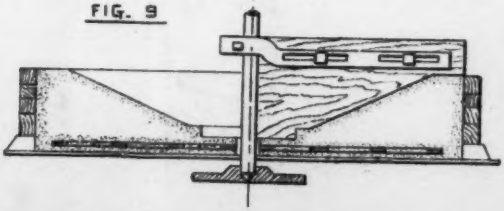


FIG. 9



tached to the cylinder. The mould of the latter is given a coat of black wash.

The second section of flask is now raised, which exposes the pattern of the upper steam port, which is accordingly removed, and thus the work of alternately removing flasks and sections of pattern continues throughout the mould. As each section of flask is removed it is gone over carefully with a sleeker, any broken edges, cracks or other defects repaired, and the face of the mould is given a coat of black wash. After this treatment the flasks are all piled upon two low iron platform cars and wheeled into the drying oven.

The sand for cores is mixed as follows: 10 pails of beach sand, 1 pail of flour, and 1½ pails of clay water. The flour and clay water give the core strength or cohesion when ramming, and render it firm and solid when baked.

In making the core for the steam ports, Plate 3, Fig. 1, the core frame, Fig. 8, is placed upon a small platform car, the top of which was previously sprinkled with parting sand to prevent the core from adhering to the plate after baking; a vent plug about 4 inches in diameter is placed in the center of the box, and sand prepared as above is added to a depth of about 2 inches. The frame, shown dotted in the core, after receiving a coat of clay wash, is now placed in position. This frame gives the core the necessary strength for handling, and is cast in the open sand, the outline being laid off with dividers and straight-edge, and the sand then scooped out with a sleeker to the proper depth. The two nests of bent wires (¼-inch diameter), three lifting staples and a quantity of nails, are printed in the mold before pouring; the nails are bent *ad libitum* after the casting is cold. More sand is now added, and when the core box is a little more than half full, a net work of gravel is laid on, radiating from the vent plug; this gives the core a free vent for the gases when pouring. More sand is added and well filled in around the wire frame forming the upper portion of the core, the whole being well rammed. The frame piece *D* is screwed in place and the sand rammed up to the top of the core box. By the use of two sweeps, one of which is shown at *F*, the upper portion of the core

is trued up; the sweep *F* is provided with a lip, by means of which it is guided along the curve *GH*, and so sweeping the upper portion of the core between *G* and *H*, the second sweep completing it from *H* to *H*. The frame *D* is now removed, the body of the core leveled off with a straightedge, and the whole carefully sleeked. The screws securing the reverse piece *C* to the sides *B* are removed, and the circular frame *A* raised from the core, after which the reverse piece is drawn away. Thin pieces of iron are braced against the sides of the core at *B* to support the sand until it gains strength by baking; for the same purpose the web space *K*, Fig. 1, is packed in with green sand. The sharp edges are trimmed off and nails impressed along the corners, as shown at *L*.

The core is now wheeled into the oven, and in this case was baked 36 hours under a low fire. Shortly after removal from the oven, the core receives a coat of black wash, consisting of pulverized Lehigh coal mixed in water. The core contains sufficient heat to thoroughly evaporate any moisture resulting from the wash.

The method of making the steam chest cores is shown in Fig. 6. A vent plug 4 inches in diameter is placed centrally in the core box, and sand shoveled in to the depth of about an inch, when two links, *A*, *A*, for lifting, and a number of core irons are placed as shown; sand is again added and rammed up to within about 2 inches of the top, when more core irons are laid, after which the whole is completed with additional sand, which is finally leveled off with a straightedge. After rapping, the rings are lifted one at a time, the core plug removed and the sharp corners of the core trimmed off, when it is placed in the oven, where it remains 24 hours. When taken out it receives a coat of black wash on its circumferential surface, the part coming in contact with the molten iron.

The upper sections of the upper steam-port core were swept up, as shown in Fig. 2. A primary sweep, *ABCDE*, secured to the finishing sweep, was first used for forming a green sand foundation ring, *BC*, after which core sand is built up on the green sand, a core frame being added, as shown. The finishing

sweep completes the core. After baking, the green sand section is scraped away.

The main cylinder core, Plate 2, Fig. 2, is made similarly to the steam-chest cores; the upper section, however, is built upon a core frame and swept up, Plate 3, Fig. 9. Although this section of core was 7½ inches deep, the same core box was used by propping it up on distance pieces, thus making one core box answer for all the sections. A core plate is used in the lower section of core, and into which three strong lifting staples are cast. As the whole weight of the cylinder core is taken by these staples, their attachment to core *irons* would be insufficient, and hence the core *plate*. These core sections were each baked 24 hours, after which they were made up as follows: The lower section was placed upon a foundation plate, *AA*, Plate 2, Fig. 2, and adjusted with a spirit level, after which the succeeding sections were placed one upon the other, a ring of dry flour making an even joint in each case.

It should be said here that, in general, it would be simpler and cheaper to sweep up a core like this in loam. The method described was adopted because the loam moulders and the whole of the foundry devoted to loam work were busy on other parts of the machinery.

To give the core (which is now of a uniform diameter) the contour of the internal surface of the cylinder, a sweep is used swung from a central spindle, which passes through the hole in plate *AA*. The sweep is first adjusted *vertically*, and the heights *B*, *C*, *D*, *E*, *F* located; the sand is then cut out between *AB*, *CD*, *EF* to the proper depth (according to the sweep) for a short distance circumferentially, with an old saw and rasp file, when the sweep is adjusted *axially*, and the sawing and filing continued around the core until the sweep neatly clears. The joints *G* of the sections are finished by scraping out a groove ¼ inch wide and about 4 inches deep, into which fresh core sand is tamped, sleeked and black washed. The whole core is tied together by means of a ⅝-inch round iron rod passing through the central vent and secured to the frames in the upper and lower core sections. The stuffing-box core is united to the

main core with a flour paste joint. The whole core is now given a coating of plumbago mixed in water, to which a little black molasses is added, which ensures the casting peeling well. After this treatment the core is placed in the oven over night, when it is ready for the mould. The joints between the different sections of the cylinder core aid in venting, rendering the use of gravel, as mentioned for the steam port cores, unnecessary. In fact, in a mould such as is now under consideration, the large body of dry porous sand contained in the flask allows of a large absorption of surface gases, and therefore very little venting is required in comparison with *green* sand moulds, where steam has to be contended with.

The mould after remaining in the oven for nine days* under a slow fire was removed, and the sections piled one upon the other in regular order in some available place on the foundry floor within radius of a swinging crane. After carefully leveling the foundation bars, already referred to, and adjusting the base plate, the first or bottom section of flask, which is the top one as piled, is lowered in place by aid of the crane and adjusted with a spirit level. This flask contains the core prints for the cylinder steam chest and lower steam nozzle cores. The order in which the mould now goes together is as follows: Lower section of steam chest core; lower steam nozzle core; 2d section of flask; lower steam port core; cylinder core; 3d section of flask; middle section of steam chest core; 4th section of flask; exhaust nozzle core; 5th section of flask; upper steam port core; 6th section of flask; upper section of steam chest core; upper sections of upper steam port core; 7th section of flask; upper steam nozzle core; water valve core; cores for side brackets; 8th section of flask or cope.

The flask sections are joined as follows: While they are suspended by the crane previous to lowering into position, the moulder removes any loose sand from their under sides by going over them with a brush; he then goes around the lower edges

*It is not necessary to leave the mould in the oven as long as this, four or five days being ample time. It was done in this instance while waiting for the completion of the cores.

of the *mould* with a trowel, scraping away a little of the sand, which results in leaving a thin fin on the surface of the casting. If this were not done, the edges would bear on each other and the corners would be crushed and broken all around the mould at each flask joint. Any cracks which may have occurred while baking are filled in with sand and plumbago mixed with a little molasses water. The edges and cracks (if any) are now painted with oil to preserve their coherence; in fact, the oil is used on a dry sand mould for much the same purpose as the water swab in green sand moulding. The top of the previous flask, already in position, is now brushed off and a trail of dry flour laid around the mould a few inches from its edges for the purpose of forming a joint with the following flask, which is now lowered in position. Between the steam-chest core sections is placed a ring of flour paste encircling the central vent preventing any chance of the molten iron working into the vent in case of any unevenness of the joint. All the core joints are smoothed off with plumbago and sand as described above for the mould.

The cores for the steam and exhaust nozzles are vented by means of a $\frac{3}{4}$-inch hole drilled several inches deep into the center of their core prints before they are placed in position; leading to these are holes drilled in the mould horizontally from the outside of the flask and filled with cinders. The cores for the side brackets are vented through the top of the cope. These cores are held in place by means of chaplets which are the only ones used in the mould excepting one for the water-valve core. The two upper sections of the steam-port core are joined to the cylinder core with a paste joint, and they are also secured by means of wires passing to the core frame of the upper section of cylinder core.

As the mould is built up, the spaces left for the necessary thickness of metal are carefully tested and corrected, if necessary, by shaving the cores; they are kept filled with waste to prevent anything accidentally dropping into the mould. The holes in the cylinder cores for the lifting rods are now filled with cinders, smoothed off on top with moulding sand and painted with oil. Before placing the cope in position a number of wads

of stiff clay are set upon the top of the cylinder core at different points; also on the steam nozzle core. The cope is now lowered in position, and, upon raising it again, these wads show the thickness of iron left for the cylinder head, nozzle, etc., any variation from the thickness called for by the drawing being corrected by shaving or patching the cores. In the case under consideration, there were practically no changes, and a slight shaving of one or two of the cores was all that was required, the mould going together without alteration. The cope contains the prints for the stuffing box, steam chest, upper half of upper steam nozzle, and side bracket cores, by which they are held in position while pouring. A ring of flour is spread around, and the cope finally placed in position, completing the mould.

Three heavy iron cross bars, similar to the foundation bars, are placed upon the cast-iron distance blocks *A*, *A*, *A*, Plate 1, Fig. 2, resting upon the top of the flask. The upper and lower bars, which project beyond the flask, are tied together with wrought-iron stirrups and straps, and by means of wedges between the bars and blocks the whole flask is strongly bound together. A rectangular wooden frame 10 inches deep and sufficiently large in area to enclose the feeding gates is built up on the cope under the cross bars. A 2-inch iron vent pipe is led through the cope to the cylinder core, the gate sticks put in place, and moulding sand shoveled into the frame and rammed up, forming a green sand basin with a circular runner to supply the twelve feeding gates. As far from these gates as possible (outside the frame) a 2-inch hole leads through the cope to the flange of the upper steam nozzle, serving as a riser and overflow. The sand is built up around this riser for several inches, in order to give the mold a slight additional head. Another hole through the cope serves as a vent to the steam-chest core. The mould is now ready for pouring.

The cupola used is of the McKenzie type, 48 inches internal diameter, and 10 feet high from hearth to charging doors. After daubing up with clay, the swinging bottom doors were propped up in place, and the melter, entering from the charging doors, lutes the joints between the doors and the base of the cupola

with clay, after which sufficient foundry sand is shoveled in at the breast hole to form a bed 6 or 7 inches thick. This is rammed and graded off towards the breast hole, which is now plastered up with clay and bricks, a pipe the size of the tap hole having been previously placed in position. The spout of the cupola is lined with clay and dried with a wood fire.

A couple of bushels of shavings and chips are thrown in, upon which logs of split pine are placed endwise on a slant against the sides of the cupola, thus protecting the luting as well as catching fire quickly; smaller pieces are thrown in between, and over all are thrown 18 bushels of fuel consisting of equal parts of coke and anthracite coal (675 lbs. coal; 360 lbs. coke). The cupola was lighted through the tap hole at 11.45 A. M. At 12.30 eight bushels more of fuel were added (300 lbs. coal; 160 lbs. coke), and at 1 P. M. commenced charging iron. At this time the bed of fuel was burning freely and had settled to about four or five feet below the charging doors. In this case no scrap was used, the mixture being composed of two parts No. 2 charcoal pig and one part of No. 1 Sloss pig, which is a soft grey iron made from ore mined in Alabama. The pigs were all broken in two, giving the pieces a length of about 12 inches. About 2,800 pounds of the iron is charged at a time, and a shovelful of oyster shells is added for a flux, and over all six bushels more of fuel (225 lbs. coal; 120 lbs. coke). This operation is repeated three times, which fills the cupola well up to the charging doors which are then closed.

(NOTE.—The mixture of pig here given does not represent the practice of the Bath Iron Works, as it was used to comply with the Navy Department specifications. In their own work, the mixture is changed by substituting, for about one-quarter of the charcoal pig, good clean scrap, such as broken car wheels. The cost of the two mixtures is about the same.)

The blast (centrifugal blower) was started at 2.45, and 15 minutes later the molten iron made its appearance at the tap-hole, which was then closed with a plug of clay on the end of the bot stick. A five-ton ladle, which has had a pine log fire burning in it for several hours, is placed under the spout and the

cupola is tapped at intervals of five or six minutes for an hour, at which time there is sufficient iron for the cast, the ladle being nearly full. Sawdust has been thrown into the ladle from time to time to check radiation. This may seem somewhat strange at first sight to those not accustomed to this use of sawdust, but experience shows that it works admirably. The sawdust is not entirely consumed but becomes carbonized and thus acts as does charcoal in the more usual practice. The layer of charred sawdust, when the ladle is full, is about two inches thick.

The ladle is now skimmed and transported to the mould by means of the crane. Just before pouring, fine sand is scattered over the molten iron to form a thin crust and gather any remaining slag and scoria. A piece of oily waste having been placed over each vent pipe and lighted, the iron is poured into the basin until there is a free discharge from the riser; more iron is afterwards slowly added until the discharge from the riser begins to clog. There is a free discharge of gas from the core vents, the flame rising from 2 to 3 feet high, and all around the sides of the flask are numerous small jets of burning carbonic oxide. Shortly after pouring, the basin is taken apart and the gates broken before they cool. The overflow from the riser is run into pigs in the foundry flow by means of a wooden trough lined with moulding sand.

The following morning, the bolts securing the brackets to the sides of the flask are first removed, after which the flask sections are lifted off in order, the cores are dug out and the casting finally taken to the cleaning room. Here the fins are chipped off, and the sand thoroughly removed with stiff wire brushes, leaving the casting ready for the machine shop, in which condition it weighed 8,170 pounds.

The H.P. and I.P. cylinders for *Gunboats Nos. 5 and 6*, and all the cylinders for the *Harbor Defence Ram*, fourteen in all, were moulded in the same general manner as described above, and with excellent results, none being lost and the castings coming out smooth and free from blow holes or other defects.

VIII.

TRANSMISSION AND DISTRIBUTION OF POWER ON MODERN SHIPS.

By Nabor Soliani, Chief Engineer, First Class, Royal Italian Navy. Translated by Walter F. Worthington, Passed Assistant Engineer, U. S. Navy.

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In modern ships the power of steam is not used solely for their propulsion, but also to perform various other operations which in old ships were either performed by hand or not at all.

Thus, on board merchant ships, a part of the available power of the boilers is now used to work the rudder, to hoist anchor, to ventilate the ship, to light it, to load and discharge cargo, to pump water, &c., and in war ships, besides these duties, it is used for others not less important, such as working the guns and torpedoes, handling ammunition, &c.

For each of these duties, which have to be performed in different parts of the ship, there are one or more special machines, to which it is required, in some way, to furnish the power which the boilers on board place at our disposal.

The means which are, or may be, adopted to attain this end are various, and the choice of a system of transmission and distribution of power well adapted to the purpose is of much importance for the efficiency and regularity of the various services on board, and for the economical performance of the same, which affects the general economy of the ship.

To give an idea of the importance of these duties, it will suffice to look at the following table in which are indicated the auxiliary machines found on board a large modern armor clad, such, for example, as the *Re Umberto* of the Italian Navy:

NUMBER AND POWER OF AUXILIARY ENGINES IN A SHIP OF WAR OF FIRST CLASS (RE UMBERTO).

Machines.	Number of machines on board.	I.H.P. (working full power) for each machine.	Total power.
Main hydraulic pumps	2	160	320
Auxiliary hydraulic pump	1	80	80
Steering engines	2	100	200
Capstan engine	1	160	160
Steam winches	2	50	100
Dynamo engines	4	25	100
Air-compressing pumps	2	30	60
Fire pumps	2	30	60
Circulating pumps	4	60	240
Main feed pumps	4	40	160
Auxiliary feed pumps	6	40	240
Bilge pumps	4	30	120
Air pumps	2	70	140
Fire-room blowers for forced draft	12	20	240
Ventilating fans	8	10	80
Turning engines	2	25	50
Reversing engines	2	25	50
Pumps for auxiliary condensers	2	20	40
Ash-hoist engines	6	5	30
Workshop engine	1	10	10
Total	69		2,480

NOTE.—The I.H.P. here given is metric.—*Translator.*

Naturally, all the machines are not working at the same time, nor at full power, and it is a high allowance, even when the ship is in action, to take the collective power of the auxiliary engines in operation at one-half of the total above indicated; but even thus reduced it is still considerable.

POWER MAY BE FURNISHED TO THESE MACHINES.

1st. By rigid or flexible mechanical means from a central motor, with shaft, gear wheel, pulleys, belts, ropes, &c.

2d. By steam, in which case each machine would have its own steam motor.

3d. By water under pressure; and then there would be a central steam motor to supply the water pressure and hydraulic motors at the points where the power is to be utilized.

4th. By compressed air; when, as in the preceding case, there would be a central motor to compress the air, and the machines to be worked would each have its own motor driven by the compressed air.

5th. Finally, by electricity, with a central generating motor for the electric current, and with electric motors attached to the machines to be worked.

Energy exists in the thermal form in the steam which the boilers generate, and therefore steam is the most direct and simple means of transmitting and distributing it where it is wanted, and in the manner and quantity desired.

It being desired to transmit and distribute the energy under another form, it is necessary, first of all, as said before, to transform it, which requires apparatus adapted to effect the kind of transformation desired.

Notwithstanding that in this way the route by which the energy reaches its place of development is rendered more complicated, and more expensive, it happens, nevertheless, in many cases, that the new form is better adapted to produce the desired effect, or it presents other advantages which make it preferable.

In ships of war, especially, energy is now developed and used, in all its forms (so to speak) and in varying quantities. And it cannot well be otherwise, since to produce electric light requires electric machines, and to propel torpedoes pumps to charge them with compressed air; but in these cases we deal with energy specially adapted to the effect desired to be obtained, while in the present article we have to do with the forms of energy which best lend themselves to the transportation and distribution of power from the boilers to the motors for auxiliary machinery of all kinds. I propose, then, to examine the advantages and disadvantages belonging to these various forms, and the limits of the field of action in each case, so that there may be established judiciously a general system, simple or compound, for transmission and distribution of energy on board ships, and best adapted to each case.

TRANSMISSION AND DISTRIBUTION OF POWER BY MEANS OF SHAFTING, GEAR WHEELS, &c.

This system of transmission and distribution of energy is not practicable on board ship, except in a very limited degree, and, in fact, is not used except in the work shop to transmit motion from the small motor to the small work-shop machinery, and in the gear of the rudder to transmit power from the steering engine to the helm. If it was desired to extend its use greatly (making no allowance for the considerable weight of the shafts for transmission and the great loss by friction), this system would entail a complication of gear wheels, pulleys and belts, and would be so inconvenient that, for this reason alone, it would be impracticable.

On the other hand, the other systems are much more practicable, and I shall give them more extended notice.

TRANSMISSION AND DISTRIBUTION OF POWER BY MEANS OF STEAM.

The system of transmission of power by means of steam is, as said before, the most simple of all, and the one most generally in use.

In the merchant marine especially, excepting some ships which have hydraulic apparatus for taking aboard and discharging cargo, all vessels have the various auxiliary machines and apparatus on board worked by steam.

In the naval service, also, steam machinery preponderates, the use of purely hydraulic apparatus being limited to working heavy guns.

With steam, no intermediate apparatus is required between the boilers and the motors of the auxiliary mechanism, and consequently there is complete independence of action for each of these engines. As long as the boilers are in use and the steam circuit intact, all the motors can continue to act, and, when a break down occurs in one of them, it is without influence on the other engines.

It should be added, also, that steam is a very pliable motive agent, that is, it is well adapted, in general, to the special conditions of action of the apparatus it is desired to actuate, especially

now that high pressures are common in the boilers; but, to offset these advantages, there are some disadvantages.

Steam as used on board ship is in the saturated state so that a small cooling suffices to produce condensation, and consequently it is necessary to use drain pipes on the steam circuit and the motive cylinders of the auxiliary machinery. Owing to its easy condensation there results another serious inconvenience, since the flooding of a compartment of the ship through which the steam circuit passes might interrupt the action of many auxiliaries at the same time. If the flooding occurred, for example, in the after part of the ship, all the motors abaft the flooded compartment, and among which would be the steering engine, would become inoperative.

The steam circuit must be complete, that is, must have two pipes, one for steam to the cylinders of the auxiliaries, and the other for exhaust from the cylinders to the condensers, from which it then passes in the form of water back to the boilers. Hence arises greater difficulty of installation and greater complication than in a system which requires but one pipe.

There is also the difficulty of the relatively great quantity of lubricant, which, from the various auxiliary steam cylinders, finds its way into the condensers and thence into the boilers, affecting injuriously their proper working and their durability.

Finally, the steam system has the disadvantage of heating greatly those parts of the ship where it passes or is applied, and of giving rise to serious consequences in cases of even slight accidents in the circuit or in the mechanism it supplies.

With regard to the efficiency of the system, considered in its entirety, that depends on two factors: that of the efficiency of the auxiliary engines, and that of the steam circuit properly so called. And it may be said at once that it is not very great, because for most of the auxiliary engines on board ship, more attention is paid to their simplicity and certainty of action than to economy of steam. Recently, however, advance has been made, and in modern ships, with auxiliary machinery working at high pressure, those auxiliaries which are intended to work often and for extended periods are made of the compound type

with considerable economy of steam. Thus, while in the auxiliary engines of the simple type, the consumption of steam varies from 30 to 35 lbs., per I.H.P., in those of the compound type the consumption is reduced to about 22 lbs. Other improvements are also possible since the best modern steam engines use scarcely 13 lbs. of steam per hour per I.H.P.

Admitting that, under present conditions, this is the minimum expenditure of steam per hour for one I.H.P. developed in the engines, the first factor of efficiency would be 60 per cent. in the case of compound engines, and hardly 40 per cent. in the case of simple engines. But the latter we cannot take into account, since their use is always limited in modern ships to secondary services required at intervals and for short periods.

The second factor—that is, the efficiency of the steam circuit—may be taken at 93 per cent., there being, as a maximum, 7 per cent. loss occasioned by the condensation, fall of pressure and resistance in the pipes to those parts most distant from the boilers. Consequently, in the present state of perfection of auxiliary engines on board, the system of transmission of energy by means of steam has a combined efficiency of about 56 per cent., which may be considered, as will be seen hereafter, very good.

The transmission of power by means of steam, if economical on board ships where it is required to transmit power at short distances, is not so on land where the distances are rather great, on account of the abundant condensation which takes place in the steam pipes.

On board ships, then, where the main engines are worked by steam, this medium is found to be preferable to any other means whatever to give motion to most of the auxiliary engines situated in the engine and fire rooms, and especially for those in which the greatest certainty and continuity of action are necessary. Among these are the pumps and the auxiliary machines which form an integral part of the motive apparatus of the ship and are essential to its action. For these machines, steam presents all the advantages of a perfect system of transmission, and fulfills most of the requirements which are peculiar to the machines themselves.

TRANSMISSION AND DISTRIBUTION OF POWER BY MEANS OF WATER UNDER PRESSURE.

This is now used on war ships for machines for working heavy guns, and in some also for steering engines, hoisting derricks, capstans and winches.

In merchant ships, hydraulic apparatus is not much used, only a few of these machines being furnished for taking aboard and discharging cargo, notwithstanding that they have shown themselves very well adapted for this service. It is probable that motives of economy in the cost of installation and maintenance are the influencing causes.

The principal advantages of this system are the simplicity of the parts of the machine in which it is used; the small liability to any serious breakage; the ease with which it is kept in working order; and, above all, the control over the working of the mechanism, which working can be regulated promptly, at will and with precision. This last quality is derived from the fact of the motive agent being a liquid, and therefore incompressible and non-dilatable, in consequence of which the working parts remain rigidly locked in the position in which they are placed by the operator as soon as he shuts off the admission of water to the machine.

In ships the system in question has also the advantage, not shared by steam, of being practically unaffected by the flooding of the part of the ship containing the hydraulic apparatus or through which passes the hydraulic circuit. The importance of these advantages for working the steering engines is evident to all. Besides, with the hydraulic system, there is no radiation to heat up excessively the compartments of the ship in which the system is used, or sprinkle them with hot water, rendering them moist and unwholesome; and an explosion of the motor, which in the case of steam might have serious consequences, would with water be innocuous.

The hydraulic system requires, like that of steam, two sets of pipes, one to conduct the water under pressure to the apparatus, the other for exhaust to reconduct it to the pumps. But there is a difference, since the hydraulic pipes are very small and

therefore easily installed in place, and have not the defects inherent in steam pipes.

Hydraulic apparatus is especially adapted to exert great power with slow motion, in a straight line of limited extent, and above all for those operations which require to be regulated with facility, certainty and precision. In this category are working the guns and their appliances for loading, the steering engines, and the derricks for hoisting.

For those operations which require other than a slow motion of the operating machinery, be this movement circular or rectilinear, hydraulic apparatus is less suitable, the use of water under pressure being adapted only to the cases where the machinery works at low speed. In the opposite case, there is great loss on account of the waste resistances in the circuit, the friction of the water through the valves and in the fittings of the hydraulic apparatus, and the violent shocks in the circuit and in the apparatus at every change of motion.

The limitation of the speed compels, as a necessary consequence, that the pressure be high.

If hydraulic apparatus is adopted, acting at low pressure and consequently with large volumes of water, it must be bulky and the piping should have a large diameter, to avoid serious loss of pressure. Apparatus and piping will be heavy, cumbrous and difficult to install; and the apparatus will not be easy to manœuvre on account of the difficulty of changing the motion of large weights of water, and there would be the inconveniences, without the advantages, of steam apparatus acting at the same pressure.

Finally, with regard to the efficiency of the hydraulic system, it is necessary that the pressure in the circuit be maintained high, and sensibly constant, which condition would be difficult to fulfill if there were in the circuit several auxiliary engines with high speed. It is for this reason that the hydraulic system has not had, in war ships, the development which for other reasons it would merit.

As has been said before, with this system is used a form of energy different from that furnished by the boilers, and for that

reason there is required a means of effecting the transformation. This consists of a pump worked by steam, which stores as mechanical energy, in the form of water under pressure, the thermal energy of steam.

The efficiency of the system is the resultant of the efficiency of the pump, of the circuit, and of the auxiliary engines. The combined efficiency of the circuit and auxiliary engines, if the resistance to be overcome by the latter does not vary, is sensibly constant, and is measured by the ratio between the initial pressure of the water at the beginning of the circuit where the pump for producing the pressure is placed, divided into the pressure with which the water acts in the auxiliary engines.

In the manœuvring of these engines, where the admission valve is opened only a little, the velocity of the water is small, and with it the reduction of the pressure in the circuit, while there is great loss of pressure in the passage of the water through the valve. The reverse happens where the valve is opened wide, so that, in the combination, the efficiency remains nearly constant. In hydraulic plants on shipboard, with the proportions in use for diameter of pipes and for the controlling valves, the combined efficiency is not less than 90 per cent. That of the supply pump is not so high.

Heretofore, hydraulic pumps in war ships have been driven by simple engines without expansion, but in more recent ships compound steam cylinders have been introduced with much economy. Hydraulic pumps are, of all the auxiliary machinery on board, the most powerful, and it is, therefore, reasonable that economy of steam should be provided for in them, especially since they have to be used in action at the very time when it is desired to obtain the maximum power from the boilers. It should be added that, with the compound engines, the desired economy of steam is obtained without affecting the regularity and certainty of action of the pump.

The efficiency of hydraulic pumps has two factors, that of the steam cylinder and that of the water end. The first, on the supposition that the steam cylinders are compound, may be taken at 60 per cent., as has already been stated in the discussion of

the transmission and distribution of power by steam direct. The second may be taken at 85 per cent., and therefore the combined efficiency is about 51 per cent. The loss of energy in the steam pipe to the pump is neglected, as these pumps are generally situated near the boilers. The efficiency of the whole hydraulic system then is about $.90 \times .51 = 46$ per cent.

With the system under discussion, the action of the auxiliary machinery is absolutely dependent on that of the hydraulic pumps. If the latter are damaged and stop working, all the auxiliary hydraulic engines become inoperative. It is for this reason that, in war ships, whenever water under pressure is used to operate mechanism where absolute certainty of action is required, and for working which no other means are provided, there are always two independent hydraulic pumps, which in time of action are both kept in operation, so that one of them suffices in case the other fails. This requirement is not peculiar, however, to the hydraulic system, but is common to all those systems of transmission and distribution of power in which steam is not used directly.

As has been said before, the hydraulic system cannot be adopted for general use for transmission and distribution of power in ships, because it is not adapted to operate machinery working at high speeds, a type now very common.

TRANSMISSION AND DISTRIBUTION OF POWER BY COMPRESSED AIR.

This system has many points of analogy with the preceding, but differs from it essentially on account of the different nature of the motive agent.

In the hydraulic system the motive agent is an incompressible and inexpansible fluid, and therefore, in the process of transformation of the energy of steam into that of water under pressure, the mechanical work done by the pistons of the pump, allowing for the losses due to friction in the pipes, ports, &c., is transferred wholly to the working cylinders of the auxiliary engines in the same form of mechanical energy without any other transformation.

In the compressed-air system, on the other hand, the fluid

being elastic, the thermal energy of the steam acting in the working cylinders of the pump which compresses the air is transferred to the compressed air partly in the same form and partly in the mechanical form. The first part, which is represented by the work of compression of the air from the atmospheric pressure to the pressure under which the system works, if not utilized in a suitable manner, may constitute a serious loss. For the very reason that the fluid is elastic, the system of compressed air lends itself very well, and within limits as extensive as those of steam, to the requirements for operating auxiliary engines, from those having slow motion to the fastest, and it is only inferior to the hydraulic in that it does not regulate and check the motion with the precision and certainty that are possible with the latter; but, as a compensation, it has advantages which place it in the front rank for transmission and distribution of power on shipboard.

First of all, the air circuit is an open one; that is, it is formed of a single pipe for carrying the compressed air from the compressors to the auxiliary engines, the air after having done its work, being discharged into the surrounding atmosphere. Moreover, the exhausted air, being cool and pure, serves wonderfully well for ventilating and cooling the compartments of the ship in which it is used, which, with the steam system, if not provided with abundant artificial ventilation, become uninhabitable on account of the excessive heat. To this may be added, that, by exhausting this air at a pressure of a few pounds above the atmosphere into the ventilating pipes, the circulation of fresh air in the compartments may be increased greatly (as much as forty fold) without the aid of any special mechanism.

Those acquainted with the difficulty of ventilating the internal compartments of modern ships will readily admit the importance of these advantages offered by the compressed air system. This system has also, like the hydraulic, the advantage of being innocuous in the event of damage to the circuit or to the auxiliary engines, the escape of compressed air not having power to injure any one nor paralyze, like steam, the whole ship.

The compressed air is also free from condensation, or at least

may be rendered so, and does not give off drops or streams of water which render the compartments of the ship damp and unwholesome, nor are pipes needed for drainage. Moreover, with compressed air, the auxiliary engines may continue to work even if the compartment in which they are placed is flooded. This advantage, which is shared by the hydraulic system alone, is an important one for the steering engine.

The compressed air system has also the special advantage of permitting, by the operation of simple valves, the use of steam in place of air to work the various auxiliary engines, in case the air compressors fail or in emergencies like fire, accidents, &c., when the compressors are not in use and it is important to lose no time getting them in operation for the purpose of working the fire pumps. In this case it would suffice that the exhaust for the air should lead into the ventilating exhaust pipes in the compartments where the compressed air engines worked. The exhaust steam would produce, as did the exhaust air, a strong exit current of vitiated air.

Finally, the system is simple, does not require pipes of large diameter, and is easy to operate. It can be applied with ease even in ships already built, of which all the auxiliary engines are operated by steam, since these work equally well with air. There is no question of introducing new and complicated machines requiring special knowledge or which are difficult to manage and require delicate handling, but only using, in exactly the same way, with a different fluid more suitable than steam, the engines which are already on board.

The field for the use of compressed air on board ship, is, then, in my opinion, very wide, and I believe it is generally adapted for all auxiliary machinery except the gear for loading heavy guns. It is, perhaps, not suitable for this purpose, which demands great simplicity and certainty in the action of the mechanism. I include among these auxiliary machines even the turret and platform-turning engines of large guns in which precision of action, on account of the great inertia of the parts in motion, cannot be obtained even with the hydraulic system. The only exceptions, to my mind, should be those auxiliary

machines which really form an essential part of the propelling engines, and thus involve long periods of continuous use, while they should also be independent of all the other auxiliaries. There may be kept for steam, also, the other and less important auxiliaries of the propelling engines, especially if situated in the engine and boiler compartments, though in many cases it will be found convenient to operate these also by air. Compressed air is also adapted in an eminent degree, to operate the engines of the dynamos which are generally placed in closed compartments and at the same time require that the surrounding atmosphere be cool. The use of compressed air would be suitable for all the engines on the upper deck where steam is subject to much condensation.

To assure the continuity of action of the auxiliary engines, it is necessary, just as in the hydraulic system, to have at least two compressors so made that one of them may be able to do all the work in case the other fails to operate. In battle both these pumps would be kept working. Under ordinary circumstances only one would be kept in use, as only a few of the auxiliary engines are usually in operation at the same time.

It is now proper to speak of the efficiency of the system. Until a few years ago, the efficiency of existing installations for transmission and distribution of power by compressed air was small on account of the imperfections in operating the system, but now, thanks to the work of Prof. Riedler, the system has been brought to such a state of perfection as to give an efficiency very high and comparable to that of the best of the other systems.

The first applications, on a large scale, of transmission and distribution of power by compressed air were made in Italy by the Italian engineer Sommeiller, for the work of boring the Mt. Cenis Tunnel. Then followed in Italy the boring of the St. Gothard Tunnel, and at Paris and at Manchester the distribution of motive power to houses by the Popp system.

In all these plants, where the problem was to distribute energy at a distance of some miles from the central generating plant, the causes of inefficiency were:

1st. The imperfections of the compressors.

2d. The useless resistance in the distributing mains.

3d. The imperfections of the motors for utilizing the compressed air.

The inefficiency of the compressors was due principally to the fact that the compression was adiabatic—that is, without cooling the air itself—so that, at the end of the compression, it contained heat which was then given out along the whole length of the piping, at the end of which, where the air was to be used, the air arrived as cool as if taken from the surrounding atmosphere. There was lost, then, an amount of work equal to the difference between that necessary to compress the air at constant heat (*i. e.*, without gain or loss of heat), and that required to compress it at constant temperature. The loss from this cause, with the air pressure of six atmospheres used in these plants, was about 30 per cent. of the useful work. Other causes of loss were the imperfections of the working parts of the pumps, and, in the first Collodon compressors used at St. Gothard, the lost work exceeded the useful work.

The efficiency of the compressors is increased by cooling the compressing cylinders by cold water jackets, and by injecting water into them; but greater efficiency has been obtained by Prof. Riedler through dividing the compression into two or more stages and completely cooling the air in refrigerators between one stage and the next. By this means he has succeeded in rendering the compression curve almost isothermic. Prof. Riedler has introduced other improvements in the details of the pumps, and especially in the suction and discharge valves of the compressing cylinders, so that he has managed to reduce to about 24 per cent., in the whole system, all the losses between the motive power developed in the steam cylinders of the pumps and the useful work available in compressed air, cooled to the temperature of the surrounding air, at the end of the pipe next to the compressors. Of these losses about 13 per cent. are due to the useless resistance of the parts and 11 per cent. to the heating of the air.

The efficiency, then, of the most perfect compressors installed on land is 76 per cent.*

But in the plant on shipboard, where the distance to which it is necessary to transfer the motive power from the central station is only a few hundred feet, the air has not time to become cooled in the pipes. Therefore, arrangements may be made so that it is not cooled to any extent and arrives warm at the motors in which it is intended to act. When this is done, all the heat of compression remaining in the air is utilized, and the loss of useful effect in the compressors is reduced to that of the useless resistance, which is about 13 per cent., and to the small losses due to clearance, leaks, &c.

To take this last into account, we will suppose that in the compressing cylinders on board ship the coefficient of efficiency of the compressors is 83 per cent. This will be also the efficiency of the whole compressing mechanism if actuated by a perfect steam engine; but since, on account of the requirements with regard to space, simplicity of parts, &c., which exist for mechanism on board ship, it is not possible to have other than an imperfect engine, we will allow, as was done in the case of other systems of transmission, that the engine of the compressing pump, compared with a perfect engine, has an efficiency of only 60 per cent.†

The whole efficiency of the compressing apparatus is then:

$$.83 \times .60 = 49.8 \text{ per cent.}$$

The loss of useful effect in the distributing pipes for compressed air, due to the leaks and the resistance of friction in the pipes, adopting for these the same diameters as were used for the steam pipes, is small and does not exceed 3 per cent. even for those points most distant from the compressors. Indeed, in the shore plant, the loss of pressure of the air in the pipes, per 100 meters length and at a velocity of 15 meters per second, which is also that which would be allowed in the ship pipes,

* This efficiency is for compressed air at six atmospheres pressure, which is more than sufficient even for the requirements on shipboard. If it is desired to compress the air to a higher pressure the efficiency would be less.

† In this case also the loss in the steam pipe to the pump is neglected.

does not exceed 1 per cent., even taking into account the resistance of the storage reservoirs. Allowing that in the pipes on board the total loss be 5 per cent., if account is taken of the losses due to bends, radiation, &c., we will suppose that the efficiency of the distributing pipes for compressed air on shipboard is 95 per cent. It remains now to see what is the efficiency of the motors which use the compressed air.

In order that a compressed-air motor may have a high efficiency, other things being equal, it is necessary that the diagram of expansion of the air in the cylinders be, as nearly as possible, the reproduction, in a contrary sense, of the diagram of compression which the air has undergone in the compressors. This condition requires, first, that in the motors the air should act expansively, and, approximately, at a ratio of expansion a little inferior to that of the compression. But that is not sufficient. In the plants on shore, without considering the loss of pressure in the pipes, it is not possible, unless special artificial means be used, to reproduce in the motors the diagrams of pressures obtained in the compressors. Indeed, the air arrives at the motors as cold as if it had been compressed at a perfectly constant temperature. Now, to compress air at a constant temperature, it is necessary to remove the heat, while to expand at a constant temperature in the motor requires restoration of the same heat. Otherwise, the air expanding adiabatically will become colder, its pressure will be less than it would have been if the expansion took place at constant temperature, and the air will produce in the motor less work than was done on it in the compressor.

Besides the loss of useful effect, unless the air is heated before use in the motors, there is the inconvenience due to the intense cold produced in the cylinders of the motors, which freezes the moisture in the air and causes obstruction in the ports. To avoid this, the first compressed air motors used the air at full pressure without expansion, and the efficiency was in reality very low, about 40 per cent. In modern motors, however, expansion is used, and, to augment the effect, the air is warmed before being admitted to the motor. This likewise obviates the

inconveniences due to the condensation and freezing of the moisture present in the air. By warming the air and injecting water into it, the efficiency can be increased to such an extent as to render the work done in the motor greater than that in the compressor. In the Popp plant, in Paris, perfected by Prof. Riedler, the air is heated with small and very simple stoves which use the heat very efficiently, so that a quarter of a pound of coal per I.H.P. suffices to double the efficiency. This is due to the fact that the heat is used about five times more efficaciously than if it was used to produce steam.

The injection of water into the air, while it passes through the stoves, has the effect of saturating the air with vapor which, condensing during the expansion, gives out its latent heat. But the greatest advantage of using the injection is of a practical nature in that it facilitates the lubrication of the cylinder walls.

By warming the air to a temperature of 150° centigrade in an old Farcot machine of 80 I.H.P., used as a motor to work by compressed air, and which was formerly worked by steam, there was obtained an efficiency of 90 per cent. of that theoretically possible. Better results can be obtained with modern motors for compressed air on the compound system, in which the warming of the air is done in two stages; but the example cited suffices to show that even when imperfect steam engines, with simple cylinders, are used as motors to work by compressed air, a high efficiency may be obtained.

It may be objected that, in the plant on shore, the efficiency is increased by heating the air artificially before admitting it to the motors, but that this could not be done on shipboard, except with much difficulty, which would take away all the advantage of the system; but, in fact, on board ship it could be done more easily, inasmuch as the air could be delivered warm from the compressors and conveyed in that condition to the motors, thus avoiding the loss of heat which occurs in the compressors used on land, and obviating the need of specially heating the air before admitting it to the motors. By regulating the compression so that the temperature of the compressed air

reaches about 150° centigrade, it is possible, as noted before, to have an efficiency, with compressed air, of 90 per cent.*

Therefore the combined efficiency of all parts of the system for transmission and distribution of power by compressed air will be: $.498 \times .95 \times .90 = 42.4$ per cent., which is little inferior to that of the hydraulic system.

TRANSMISSION OF ENERGY BY MEANS OF ELECTRICITY.

This system is a very valuable means of conveniently transmitting power to great distances, where other methods would not be adapted, and it also has special advantages on account of the facility and simplicity with which the power can be distributed to the motive machines, whatever may be their number, wherever they may be situated, and in whatever manner placed. Moreover, so important and frequent are the discoveries which are made with regard to electric phenomena, and so rapid is the progress in applying them, that we have reason to believe that, in the near future, electricity will be the principal agent in the service of human activity. But it is not my province to enter into these speculations, nor to consider the question of transmission and distribution of power in general, but only to consider the circumscribed and special case of ships, and that only under present circumstances.

Even in the present condition of development of the applications of electricity, it is possible on board ship to perform with electricity the greater part of the operations which are now performed by steam, hydraulic power, &c. Indeed, by using compound-wound dynamos (which are properly designed for furnishing a variable current at constant potential, though the speed is uniform), and also compound-wound motors, placed on branches of the main circuit, these motors can be run at con-

* With this temperature of admission, the air could exhaust from the motor, cooled down to a few degrees above 0° centigrade, if acting with sufficient expansion. While in many of the auxiliary engines on board this result would not be possible, it would still not be undesirable, as already shown, for the auxiliary engines situated in the interior compartments of the ship, if the arrangement could be made for exhausting into the ducts for vitiated air, so that these engines could be worked by steam, in case of a failure occurring in the compressed air system.

stant speed whatever the variation in the work coming on them. They are also entirely under the control of the operator, and the working of each one is independent of the others, and does not alter the speed of the generating dynamos. This desirable result is obtained more readily on shipboard on account of the short length of the circuit which reduces the resistance to a minimum.

Thus, under suitable conditions, the speed of the auxiliary engines may be varied, although not within such wide limits as is possible with other systems of transmission. If it is desired to change the speed from the normal, there is a loss of useful effect, but this loss is not very important, since the motors which are intended to run continuously ordinarily maintain a normal speed, which has to be altered only rarely; and this regularity of speed is the more easily preserved because it is governed automatically and does not, as in other systems, respond at once to a change in the resistance.

The installation of the circuits for the transmission of power presents little difficulty with electric wires, which can be bent as desired, made to pass anywhere, and easily reunited if broken. With electric motors there is no radiation of heat, nor dripping of hot water, to render the compartments of the ship where they are placed excessively hot and damp; and the most simple movement of a switch or the lever of a rheostat suffices to start, speed up, slow down, or stop the motor at will. Electricity, therefore, in its present state of development, satisfies the principal requirements desired for a system of transmission and distribution of power. It may also be said that it presents advantages not afforded by other forms of energy, and, on this account, in many cases, may be preferred. But, on the other hand, it has peculiarities of its own which limit its application on shipboard.

One special requirement of dynamo-electric machines and electric motors is that the peripheral velocity of the armatures shall be great; whence, in the case of machines and motors which are to have relatively small dimensions, the required velocity will be excessive. This case occurs on shipboard where, for economy of space and weight, all machines are made

as small as possible. This does not affect the generating dynamo, but, for the motors, it involves interposing gear wheels or other devices for reducing the speed between them and the auxiliary mechanism to be operated if the latter must work more slowly.

As a consequence, electric motors are especially appropriate for apparatus which is to work at high speed, and are not adapted for machines which have a slow motion, or where the intermediate parts necessary to reduce the speed are found inconvenient or cumbrous, as these parts, while complicating the apparatus, are also, in general, a source of notable loss of power.

Electric apparatus is, moreover, different from ordinary mechanical apparatus, on account of the delicacy of its organs and the subtle nature of the agent which pervades them. However great the improvements made in electric apparatus, it is undeniable that its action is uncertain and can be affected by small causes which are not always easy to discover with rapidity or to eliminate. For example, a contact established between two branches of the principal circuit can paralyze all the motors, and even produce irreparable injury to the generating machine. Even when the effects of the contact or of other disturbing cause are not so grave, it is not easy, as a rule, to find these causes quickly and remedy them. This will be confirmed by those who have had experience in the use of the electric light on shipboard, where it occasionally happens that much time is required to find out the cause of the failure of some circuit of the generating dynamo. If a pipe bursts or a piece of mechanism breaks it is easily seen, and even persons with little skill can see at once what is necessary to be done to provide a remedy. If, however, any accident happens inside of electric apparatus or in any part whatever of the circuit, it requires an electrician to exercise his ingenuity to discover quickly the reasons, and all his ability to put things to rights, if, indeed, that is possible.

This lack of certainty (which may be, indeed, transitory) makes it inexpedient, at least for the present, to apply electricity as a motive power for any mechanism which should be certain and continuous in its action, or which cannot be worked promptly

by other means when electricity fails. Among these machines are the auxiliary engines which form an integral part of the main engines of the ship, and also the steering engine.

In France, electric motors have been used successfully to train and elevate guns; but this is for small and medium-sized guns, which can also be worked by hand, and it is still a matter of doubt whether electricity is suitable for heavy guns.*

On the other hand, electric motors are well adapted to run ventilating fans, both because they should revolve rapidly and because there is no great harm done if they should fail to work.

As in the case of hydraulic or compressed air transmission, so in the case of electricity, it is necessary, in order to assure as far as possible the continuous action of the motors, that there should be at least two generating dynamos to be used together in case of going into battle.

Electricity is also inferior to water and compressed air with respect to immunity from damage in case of a flooded compartment, since the electric motors, situated in the flooded compartments, would necessarily cease to work. The flooding might also put in communication the branches of the principal circuit and produce the serious effects already mentioned. For the same reason, electric motors are not well adapted for apparatus on the upper decks which remain exposed to spray and the inclemencies of the weather. Finally, electric motors are not adapted for machinery designed for manœuvring, such as the steering and capstan engines, &c., in which the resistance to be overcome may vary suddenly and may be greater than the motor is able to overcome, since, in such event, the current in the armature might become excessive and cause damage.

On the whole, there is not, it seems to me, so wide a field for the application of electricity on board ships as at first sight appears, and many improvements must be made before electricity can advantageously be used to replace other means which are

* In the French armor-clad *Jauréguiberry*, the construction of which has been begun by the Company "Forges et Chantiers de la Méditerranée," the turrets of the 15, 27 and 30-centimeter guns, which can also be worked by hand, will be furnished with electric motors. It appears also that in this ship electricity will be used for other purposes.

now in use for the transmission and distribution of power. This does not mean that these improvements will not be made. Even if they are not certain, they are at least very probable, and perhaps some day electric motors will do the work of the main engines on shipboard. When electric energy can be stowed on board as coal is now, or when it becomes possible to transform the energy stored in the latter directly into electricity, this will be possible.

I shall now say a few words on the efficiency of the system. All authorities agree that for short distances this efficiency is very high. If the generating dynamos and motors are well proportioned and work under normal conditions, they give an efficiency of not less than 75 per cent. between the engine of the dynamos which generate the current and the motors, that is to say, between the power developed by the steam at the pistons of the motive engine and the power of the electric energy at the armatures of the motors. We may accept, without making any serious error, that this last corresponds to the power developed at the pistons of ordinary motors using water or compressed air, and therefore the said efficiency will be comparable to that which, in the case of transmission and distribution of power by water or compressed air, exists between the power developed by the steam in the cylinders of the engines of the compressors and the power developed by the water or compressed air in the motive cylinders of the auxiliary machinery.

If, as in these cases, we suppose that 60 per cent. be the efficiency of the motive engine of the dynamo, the combined efficiency of all parts of the electric system of transmission and distribution of energy is:

$$.60 \times .75 = 45 \text{ per cent.},$$

which differs little from the efficiency of the other indirect systems of water and compressed air.

COMPARISON OF WEIGHT, COST, SPACE OCCUPIED, AND WORKING EXPENSES OF MOTORS FOR AUXILIARY MACHINERY, BY THE DIFFERENT SYSTEMS OF TRANSMISSION AND DISTRIBUTION OF ENERGY ON SHIPBOARD.

First, to sum up the results of the examinations of the various systems and to deduce conclusions as to their relative adaptability for auxiliary mechanism on shipboard, it is desirable to

make the comparison from the point of view of weight, cost, and space occupied, of the apparatus necessary for them, and of the necessary running expenses whenever one of these is adopted to the exclusion of the others.

To fix our ideas, I shall take the case of a war ship of the first class, of which I have given the number and power of the auxiliary engines, the maximum collective power of the auxiliary machinery in use, when the ship is in action, being 1200 I.H.P. I shall also assume that the circuits for the transmission and distribution of energy have the same extent in all cases, and that their weight is proportional to the unit weight per running meter of the principal branches which compose them; and, finally, to establish approximate figures for comparison, I shall assume in all cases that the weight of the whole circuit, including the branches, is equal to that of main lines with a length of 200 meters, and with a cross-section which remains constant and equal to that it has at the beginning.

SYSTEM BY STEAM.

In this system there is only to be considered the circuit for the steam, and the steam engines of the various auxiliary machines.

To convey the steam required for 1,200 I.H.P. at the pressure of five or six atmospheres, such as is used ordinarily on board modern ships, steam pipes will be required of about 20 cm. (8 inches) diameter, weighing 30 kilos per running meter (20 lbs. per foot); therefore the total weight of the steam circuit will be $2 \times 200 \times 30 = 12{,}000$ kilos (12 tons).

The weight of the motive engines of the auxiliary machinery of modern ships varies from 20 to 50 kilos (45 to 110 lbs.) per I.H.P., according to the type of the engines and the speed at which they work, and the manner in which they are connected to the apparatus they are designed to operate. Taking the mean figure of 40 kilos (88 lbs.) in the case of the ship used as an example, which has about 2,400 I.H.P. in auxiliary apparatus,* we have for the motive engines a total weight of 96 tons.

*Although it is assumed that the I.H.P. actually developed is 1,200, it must be remembered that the machinery provided would, if *all* in use at once, give 2,400, and it is on this latter figure that the *weight* of the auxiliary machinery must be based.

Allowing 5 francs per kilo for steam pipes and 3 francs per kilo for motors, including mountings, the cost of the installation of the system of steam amounts to 60,000 francs for the first and 288,000 francs for the second.

With regard to the space occupied by the pipes and by the motors, the calculation will be based on the density (*i. e.*, weight divided by the volume). It may be allowed that in the apparatus on board ship the density of piping is .8 and that of the motive engine is 1.2.

That being settled we have for the system by steam:

	Circuit.	Motors for Auxiliaries.	Total.
Weight in tons	12	96	108
Cost in francs	60,000	288,000	348,000
Volume in cubic meters	15	80	95
Cubic feet	530	2,825	3,355

HYDRAULIC SYSTEM.

In this case there will be required for the principal branches of the circuit, piping of about 12 cm. (4.7 ins.) internal diameter which will weigh on an average of those for admission and for exhaust 30 kilos per running meter (20 lbs. per foot). Therefore, according to the preceding hypothesis, the weight of the hydraulic circuit will be also 12,000 kilos (12 tons). But, while there is no increase of weight in the circuit, it is very different when we come to the motors, which are much heavier than steam engines, and weigh from 100 to 300 kilos (220 to 660 lbs.) per I.H.P., the lower figure being for those working moderately fast and the latter for very slow speeds. Adopting the lower figure which is the one that will apply to the greater number of them, we have for hydraulic motors a weight of 240 tons. To this weight it is necessary to add that of the hydraulic pumps to furnish the water.

Suppose there are on board five pumps, so that four are sufficient for the service and the fifth is held in reserve in case one of the others fails to work. Each of these pumps should have an

I.H.P. of about 400, and would weigh about 30 tons. Therefore we would have for the five pumps a weight of 150 tons. It is necessary, finally, to add the weight of water circulating in the system and that in the accumulators, which will be a total of about 40 tons.

The density of the circuits and hydraulic mechanism, without water, is greater than that of the circuits and mechanism for steam, and we may take as a mean the following figures: density of circuit = 2.5; mechanism = 2; accumulators with water = 1; whence:

	Accumulators and water.	Circuit.	Machines for transforming energy.	Motors for Auxiliaries.	Total.
Tons.....	40	12	150	240	442
Francs	10,000	60,000	450,000	720,000	1,240,000
Cubic meters.....	40	4.8	125	120	289.8
Cubic feet.....	1,400	170	4,400	4,225	10,195

SYSTEM BY COMPRESSED AIR.

In this system the circuit is open, that is, it consists of a single main which conducts the compressed air to the motive engines of the auxiliary machines, and thus there is saved all the exhaust piping which is necessary with the other systems.

For the transmission of air, pipes like those for steam will serve since the air is used at the same pressure. The weight of piping will be about 40 kilos per meter (27 lbs. per foot), and since its extent is one-half that of the preceding we shall have for the circuit a weight of $40 \times 200 = 8{,}000$ kilos (8 tons). The auxiliary engines remain the same as those used in the steam system and we already know their weight. To the weights already mentioned, it is necessary to add that of the air compressors. In this case, also, we shall suppose that there are five compressors of 400 I.H.P. each. Their weight is about 100 kilos per I.H.P., or a total of 200 tons.

We shall have, then, for the compressed air system, adopting always the same coefficients:

	Circuit.	Machines for transforming energy.	Motors for Auxiliaries.	Total.
Tons	8	200	96	304
Francs	40,000	600,000	288,000	928,000
Cubic meters	10	166	80	256
Cubic feet	355	5,950	2,860	9,165

SYSTEM BY ELECTRICITY.

In the plants at present used on shipboard, a very low potential is used, ordinarily 65 volts, which for electric light service seems suitable; but it would not be practicable in the case of a general system for the transmission and distribution of energy because of the enormous current which it would be necessary to pass through the circuit. Indeed, allowing an electric efficiency of 90 per cent. between the generating dynamo and the electric motors, the electric power at the beginning of the circuit should be 1,333 H.P., to produce which, with a potential of 65 volts, would require a current of 15,000 amperes. And since the circuits would be insulated and would not transmit a current of over two amperes per square millimeter of section, it follows that, at the beginning, the two branches of the circuit should each be composed of a bundle of 75 wires with a cross-section of one square centimeter each. The weight of the whole circuit would be about double that calculated for the steam or water circuits.

Moreover, it would not be practicable to use such a low voltage on account of the difficulties which would be encountered in installing on board ship dynamos developing more than 1,000 amperes, and because to obtain all the power necessary with machines of 1,000 amperes would require a battery of fifteen dynamos. With so many machines in operation, the probability of breakages would be great, and it would be difficult to obtain from them the regularity of action which is requisite. It would be necessary, then, to have fewer generating dynamos. This can be done by increasing proportionately their potential. Thus, with a potential of 200 volts, the number of dynamos required would be reduced to five, a number which is admissible. An

extra dynamo should be provided for use in case one of those in operation broke down.*

Adopting this solution, the weight of the circuit would be reduced to a third of the preceding, and then it would be about $\frac{2}{3}$ of that calculated for steam or water. The six dynamos would have to be driven by steam engines of 320 I.H.P. each. Estimating the combined weight of the dynamos and engines on the basis of 100 kilos per I.H.P., which figure is rather low, this gives a total weight of 192 tons. Electric motors weigh from 50 to 100 kilos per H.P., according to the type, speed, &c. Supposing we adopt the lightest, the weight of the motors required to actuate all of the auxiliary machinery on board, which requires a total of 2,400 I.H.P., would amount to 120 tons.

Applying the coefficients previously established in the case of steam for the cost of this apparatus and space occupied, which are sufficiently applicable to the case in question, we have:

	Circuit.	Machines for transforming energy.	Motors for Auxiliaries.	Total.
Tons	9.6	192	120	321.6
Francs	48,000	576,000	360,000	984,000
Cubic meters	12	160	100	272
Cubic feet	425	5,650	3 530	9,605

Comparing the results in the foregoing tables, it will be observed that, for saving of weight, cost and space, the system of transmission by steam direct is best.

Next to this come the systems by electricity and by compressed air, which are very nearly equal, and last comes the hydraulic system which is heavier and more expensive.

Also, with respect to cost of working, the system by steam direct must necessarily be better.

* For the electric-light service, which requires a lower potential, it would probably be found expedient to provide the special machines and circuits now in use. I do not take this into account, and suppose, for the sake of simplicity, that the electric-light service is supplied by the large dynamos used for the transmission of power.

Assuming that the cost of maintenance is proportional to the first cost, and the efficiency of the three indirect systems being very nearly the same, the best, after steam direct, will be the electric system; but it is necessary to observe that this costs about the same as the compressed air system, and, since the electric apparatus is much more delicate than that of the air system, it may happen that the greater cost of maintenance of the former will render the compressed air system more advantageous.

CONCLUSIONS.

From the foregoing facts the following conclusions may be drawn:

(1.) The system of transmitting power by steam direct is, for efficiency, regularity, and certainty of action, and saving of weight, space and cost, most desirable. Consequently, for the generality of cases this is the system to be preferred, and it is preferred.

Admitting, however, that, for special reasons, it is found convenient to work the auxiliary machinery by one of the indirect systems, steam being the original source of energy and perfect reliance being placed upon it, there should be left for steam all of the auxiliary machinery which forms an integral part of the motive machinery of the vessel, and which is necessary for the working of the ship.

These engines are the air and circulating and feed pumps, reversing engine, and in general all the auxiliary engines in the engine and fire rooms.

(2.) The hydraulic system is not suitable for general use; but is very well adapted for working heavy guns. In case it is used for this purpose it may also be used with advantage for steering.

(3.) The compressed-air system may be used with advantage for all of the auxiliary engines on board with the exception of those which form an integral part of the motive machinery of the vessel, for the reasons mentioned in section 1, or those which work the heavy guns, for which latter purpose the hydraulic system is preferable. But the ammunition hoists and turret and platform turning gear may be advantageously worked by compressed air.

(4.) The electric system is not adapted for general use for the transmission of power, but may be used for working medium and light guns, and for operating machinery designed to run at high speeds, such, for example, as ventilating fans. But in case compressed air is in general use on board ship for the transmission and distribution of power, it would be preferable to employ this rather than electricity for the ventilating fans also, especially if these are exposed to coal dust.

Applying the rules thus laid down to the case under consideration of a war ship of the first class, we shall have for the various means of transmission and distribution of power the following division of the auxiliary machinery:

REDISTRIBUTION OF VARIOUS AUXILIARY MACHINES ON BOARD OF A FIRST-CLASS WAR SHIP, ACCORDING TO THE MOTIVE AGENT SUITABLE FOR THEIR OPERATION.

Motors.	I.H.P. total.	Redistribution.			
		Steam.	Water.	Comp. air.	Electricity.
Main engines	19,500	19,500	...	...	...
Circulating pumps	240	240	...	...	...
Main feed pumps	160	160	...	...	...
Auxiliary feed pumps	240	240	...	...	...
Pumps for auxiliary condensers	40	40	...	...	...
Bilge pumps	120	120	...	...	...
Turning engine (for main engines)	50	50	...	...	...
Reversing engines	50	50	...	...	...
Fire pumps	60	...	...	60	...
Main air pumps	140	...	...	140	...
Air compressor for torpedoes	60	...	...	60	...
Hydraulic pumps	160	...	...	160	...
Steering engines	200	...	...	200	..
Capstan engines	160	...	...	160	...
Winches	100	...	...	100	...
Dynamo engine for electric light	130	...	...	130	..
Blowers for fire room	240	...	...	240	...
Blowers for ventilation	0	...	...	0	...
Ash engines	30	...	...	30	...
Work-shop engine	10	...	...	10	...
Gun and turret-turning engine	160	...	...	160	...
Ammunition hoists	100	...	...	100	...
Air compressors	1,250	1,250	...	...	...
Hydraulic gear for loading guns, &c.	...	...	120	...	...
Electric light	...	...	...	...	100
Electric motors for rapid-fire guns	...	...	...	...	20
Total	...	21,650	120	1,550	120

According to this redistribution, there will be provided for the machinery worked by compressed air, a collective I.H.P. of about 1,500; but, taking into account only those auxiliaries which in battle would be in operation at the same time, it would suffice to have a power available in compressed air of 800 I.H.P. which would be furnished by four main compressors of 250 I.H.P. each. There should also be an auxiliary compressor of 250 I.H.P. in case one of the main ones broke down.

The weight of the machinery on board, by the addition of the compressors, would be increased only about 125 tons.

IX.

THE ELECTRIC PUMPING PLANT FOR THE SALT WATER AQUARIA, WORLD'S COLUMBIAN EXPOSITION, CHICAGO, 1893.

By P. A. Engineer W. B. Bayley, U. S. Navy.

In designing the pumping plant for the salt water aquaria to be constructed under the direction of the U. S. Fish Commission for the World's Fair to be held at Chicago in 1893, three important problems were presented for solution:

1st. The water must at all times be clear and transparent.

2d. It must be free from impurities of any description that would endanger the life or health of fish and sea anemone.

3d. The temperature of the water should not vary more than is usual in large bodies of salt water, and aquaria containing specimens from waters of different latitudes should be maintained as near the temperatures of those waters as possible. In other words, some method of regulating temperatures must be provided.

It is evident that, unless some automatic or mechanical means for maintaining the above conditions is provided, the comparatively small body of salt water—about 65,000 gallons—which in this case is required to be used over and over again, would very soon become opaque, tepid and unwholesome, in which organic life could not exist.

To accomplish the first result, a system of filtration is provided, consisting of alternate layers of coarse sand and gravel through which the water is filtered after leaving the aquaria.

As to the second problem, it is only necessary that the reservoir, tanks, pumps and piping be constructed of material not easily affected by contact with salt water. Should iron be used for the pumps and piping, the water would soon be discolored, due to the corrosive action of salt water in contact with iron. Brass, or composition, the material most used in the construction

of pumps and piping for salt water, would not be possible in this case from the fact that the copper in the composition would slowly but surely poison the water. A rubber pumping plant having been installed for the use of the salt water aquaria at Washington about two years ago by the writer, and during that time having given satisfaction, it was decided to use this material for the Chicago plant.

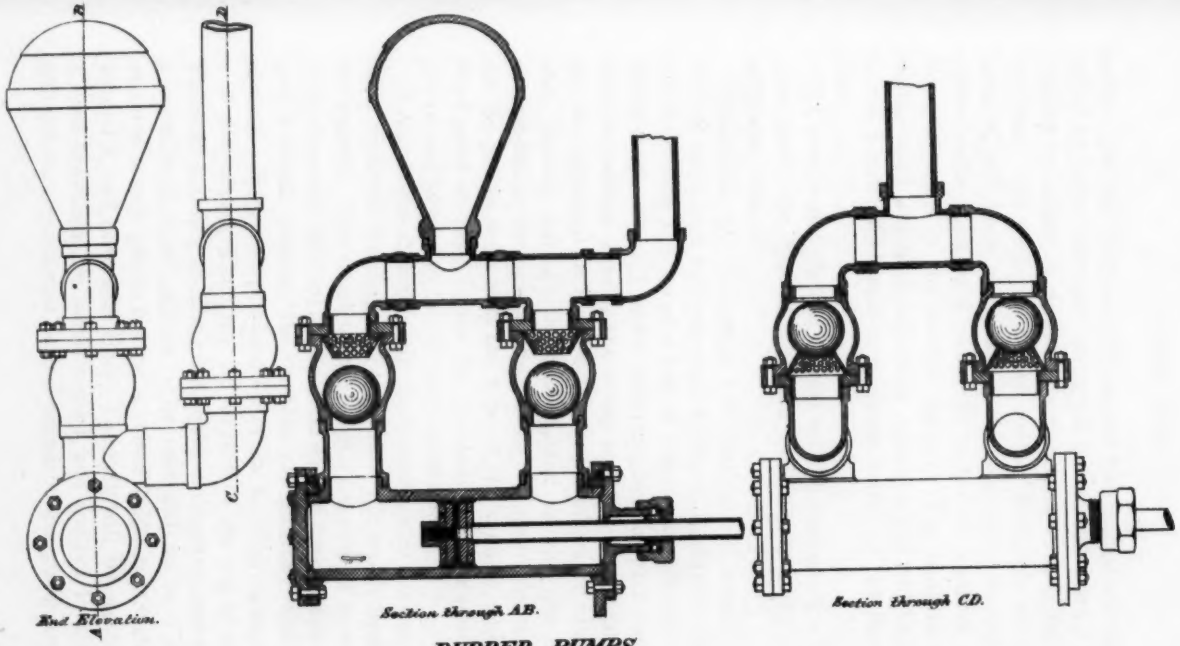
For the purpose of regulating the temperature of the water before entering the aquaria, the supply pipes, two in number, pass through two reservoirs. A circulation of hot water in one and cold water in the other is maintained through the reservoirs and around the supply pipes, the flow and consequently the temperature of the circulating water being regulated by suitable valves, so that the temperature of the salt water passing through the supply pipes can be easily regulated.

The following copy of the specifications will better describe the construction of the plant, and in offering them to the inspection of the readers of the JOURNAL the writer does not claim originality in the use of hard rubber for the pumps and piping, a steam pumping plant, on a smaller scale, of rubber with pumps similar to those herein described, having been constructed for the old New York aquaria, if he is not mistaken, by the Goodyear Rubber Co., New York, several years ago.

Only those parts of the drawings which accompanied the specifications are here given which relate to the features differing from ordinary practice.

SPECIFICATIONS.

Pumps and Motors.—There will be two reciprocating direct-acting force pumps of hard rubber, with cylinders 10 inches by $4\frac{3}{4}$ inches, having a capacity of 4,000 gallons of water per hour each at 90 strokes per minute, and driven by two electric motors of about 6 H.P. each, at 700 revolutions per minute. Each pump will be connected by a crosshead and connecting rod to a wrist pin in a balance wheel fitted on each end of a shaft carried in bearings on the casting which forms the crosshead guides, and to which is also bolted the casting forming the bed of the rubber



RUBBER PUMPS.

for the

Salt Water Aquaria,

U. S. Fisheries Exhibit.

Worlds Columbian Exhibition,

Chicago.

pump. On this shaft and between the two pumps will be a belt pulley 42 inches diameter connected by a 6-inch leather belt to a pulley 10 inches in diameter on the center of a counter shaft overhead. On each end of the counter shaft, and outside the hangers, will be a pulley 42 inches diameter connected by a 4-inch leather belt to a pulley 12 inches in diameter on the armature shafts of the electric motors. The hangers for the counter shaft will have adjustable bearings, and will be secured to two 3-inch by 12-inch cross pieces bolted to the floor joists above.

The pumps and electric motors will be located in a separate room under the floor of the main Fisheries building near the salt water reservoir.

Foundations for the pumps and motors will consist of two 12-inch by 15-inch well seasoned hard pine timbers 15 feet long, laid flush with the top of a bed of concrete 4 feet wide and 18 inches deep. Bolts $\frac{3}{4}$-inches diameter, four at each end of the frame or casting forming the pump bed and crosshead guides, will be embedded in the concrete with washers on their lower ends, passing through the timbers, and forming the holding-down bolts for the pumps and motors. If desirable, these bolts can be put in flush with the tops of the timbers, and square-head wood screws $\frac{5}{8}$ inches by $3\frac{1}{2}$ inches used for securing the pumps and motors to the timber foundations.

A Salt Water Reservoir will be located under the floor of the main Fisheries building near the end of the arcade leading into the aquaria. The reservoir will have a capacity of about sixty-eight thousand (68,000) gallons, and will be constructed of brick and Portland cement, the bottom of concrete, and surface asphalt. (Reservoir provided for in the building contract.)

A Distributing Tank will be located in the top of the main Fisheries building about 54 feet above the aquaria, and will have a capacity of 2,500 gallons. The tank will set in a drip pan made of 2-inch plank, having a raised ledge two inches high around it, and lined with zinc. The tank will be provided with a float connected by suitable cord and pulleys to a movable pointer on a graduated scale located in the pump and motor

room, which will indicate accurately the depth of water in the tank. (Tank provided for in the building contract.)

A Filter will be located under the floor of the arcade, at the end nearest the aquaria. It will be constructed of 2-inch plank 12 feet by 4 feet by 2 feet, and will be filled with layers of coarse gravel and fine sand, through which all of the water will be filtered after passing through the aquaria. (Provided for in the building contract.)

Apparatus for Regulating the Temperature of Water.—For the purpose of regulating the temperature of the water in the aquaria in summer and winter to any desired temperature, there will be set up in a convenient place in the arcade, near the aquaria, two sections of 12-inch wrought-iron pipe, secured to the joists with suitable hangers. Each section will be 12 feet long, and provided with cast-iron flanges screwed on the ends, to which will be bolted cast-iron heads, through which will pass the 2-inch rubber supply pipes with a lock nut on each side of the head, thus making the 12-inch sections or reservoirs steam and water tight. The pipes will return once inside the 12-inch section, thence to the aquaria. Before entering the 12-inch section each of the 2-inch pipes will be fitted with a cock for the purpose of regulating the flow of water. The two sections of 12-inch pipe will be covered with hair felt 2 inches thick, and then with canvas sewed on. The supply pipes from the refrigerator and heater, as well as the 2-inch rubber pipes after leaving the 12-inch sections, to be covered with non-conducting material.

There will be supplied and erected in a convenient place in the arcade near the aquaria a refrigerator of the most approved construction, large enough to hold 300 lbs. of ice. On the inside of the refrigerator and secured to the sides will be about 120 feet of ½-inch iron pipe in flat coils. Before entering the refrigerator the ½-inch iron pipe will be connected to the city water supply, and after leaving the refrigerator will connect with one of the 12-inch sections of pipe containing the 2-inch rubber pipe supplying the aquaria. After circulating through the 12-inch and around the 2-inch pipe, the water will be returned to the refrigerator.

The other 12-inch pipe will be connected to the heating system of the building for the purpose of increasing the temperature of the water entering the aquaria when necessary. In case no heating system is provided for the building, there will be erected in a convenient place in the arcade a small hot-water heater of approved type. The supply and return pipes of the heater to be connected to the 12-inch section to enable a circulation of hot water through the 12-inch pipes and around the 2-inch supply pipes to be maintained.

A cock or valve on the supply pipe to the hot and cold water reservoir, through which the supply pipes to aquaria pass, will enable the temperature to be easily regulated.

Rubber Piping.—There will be four pipes connected with the distributing tank, viz: Two 2½-inch delivery pipes, one from each pump; one 2½-inch supply pipe connected near the bottom of the tank, provided with a cock close to the tank and leading down to the arcade. In the arcade the 2½-inch pipe will branch into two 2-inch pipes, and, after passing through the apparatus designed for regulating the temperature of water, these will continue on to the aquaria, where they will lead side by side over the top of the the outer row of aquaria, making one supply pipe for each set of aquaria. In each of these 2-inch pipes over the aquaria there will be 96 $\frac{1}{16}$-inch rubber jet cocks—192 in all; the cocks supplying the outer row of aquaria will point downward, and those for the inner row of aquaria will point upward and connect with them by flexible rubber tubing. One 2½-inch overflow pipe, connected near the top of the tank and leading down to the main reservoir.

All of the pipes to and from the main distributing tank will be led under the floor of the main Fisheries building to the nearest available column, and will then follow the line of columns to the tank above. A 1½-inch drain pipe fitted with a cock will connect the bottom of the tank with the overflow pipe, so that the tank can at any time be drained into the main reservoir. The drip pan in which the tank sets will also be connected to the overflow pipe by a ¾ inch pipe. There will be a 3-inch suction pipe with a suitable strainer provided for each

pump. A 1½-inch drain pipe and cock will also connect the end aquarium in each row with the 2-inch pipe, to be used for draining the aquaria if necessary. A 2-inch pipe from each row of aquaria uniting into one 3-inch pipe will conduct the water from the aquaria to the filter, and a 3-inch pipe will conduct the water from the filter to reservoir. The 3-inch pipe from the aquaria will also connect directly with the 3-inch pipe to the reservoir, suitable cocks being provided in order that, if found desirable, the water can be returned direct from aquaria to reservoir without passing through the filter.

There will be a ¾ inch drain pipe and cock from each of the 2½-inch delivery pipes connecting with the main reservoir at some point in the pump and motor room for the purpose of draining the pipes, should repairs be necessary at any time to the pumps. There will also be a ¾-inch drain cock on the extreme end of the 2-inch supply pipes over the aquaria and connecting with the return pipe to reservoir.

All pipe conections with the tank, filter, apparatus for regulating temperatures and overflows from the aquaria will be made with lock nuts. Suitable hangers for the piping will be provided where necessary. The overhead horizontal sections of piping will be provided with drip pans for the purpose of collecting the moisture deposited on the outside of the pipes in warm weather, and which would otherwise drop down on the floor beneath. These pans can, if necessary, be drained into the overflow pipe.

Material.—The pump cylinders, cylinder heads, valves, valve seats, water passages, air chambers, pistons, piston rods, stuffing boxes, all pipes and fittings, cocks, lock nuts and any part or portion of the pumps and piping with which the salt water comes in contact, will be of the best hard rubber or vulcanite, and both pumps and piping must be tested to a hydrostatic pressure of 75 lbs. per square inch, and be capable of withstanding a constant working pressure of 40 lbs. per square inch. The "ball"-pump valves to be cast hollow, or if preferable, around a central core or sphere of sheet metal or wood, so that the weight of the valve will be a little less than that of the water displaced. All elbows, tees, couplings and unions to be of cast iron lined with hard

rubber. A cast-iron flange will be screwed on each end of the rubber-pump cylinders, and to these cast-iron flanges the rubber-pump heads will be bolted.

The pump pistons will be made of rubber in two parts or discs, each disc 1 inch thick. Between the two discs will be two thicknesses of $\frac{3}{16}$-inch leather shaped in a "former" for the purpose of packing the pistons. A single groove will be cut around the circumference of each disc, this groove to connect with $\frac{1}{16}$-inch holes drilled in the side of the discs for the purpose of forcing out the leather packing when a pressure of water is on either side of the piston, thus insuring tightness. The piston rods will be 1-inch steel covered with a $\frac{3}{16}$-inch thickness of rubber.

The bed or frames for the rubber pumps, and which also form the crosshead guides and bearings for the balance-wheel shaft, will be of cast iron. There will be two of these frames, one right and one left. Crossheads will also be of cast iron; crosshead pins and wrist pins of steel; connecting rods of wrought iron, fitted with brasses on the end, attached to the wrist pin in the balance wheels. All bearings to be of cast iron, lined with Babbitt's metal and fitted with sight-feed oil cups.

Operation of Plant.—The pumps must have separate suction and delivery pipes, and be run by separate motors, so that each pump will be independent of the other. They will be strictly interchangeable, making two separate and distinct plants; and in case of accident to one pump or motor, or of any of its attachments, the other must be capable of supplying enough water for the aquaria. The water will be drawn from the reservoir by the pumps through the 3-inch suction pipes, and pumped into the distributing tank through the $2\frac{1}{2}$-inch delivery pipes. From the distributing tank the water will be conveyed to the arcade connecting the main Fisheries building with the aquaria by the $2\frac{1}{2}$-inch supply pipe; thence through the apparatus for regulating the temperature by the 2-inch pipes to the aquaria, into which the water will be discharged through the jet cocks.

After passing through the aquaria the water will be conveyed by the 2-inch return pipes to the filter, and from the filter to the reservoir by the 3-inch return pipe.

X.

THE PROPOSED REVISION OF THE RULES OF THE STEAMBOAT INSPECTION SERVICE.

By Passed Assistant Engineer Walter M. McFarland, U. S. Navy.

The following remarks are intended merely as an introduction to those sections of Senate Bill 1755, introduced by the Hon. Wm. P. Frye, which relate to machinery and the qualifications and examinations of engineers in the merchant marine of the United States.

For some years past there has existed among engineers who have had to do with the rules of the Steamboat Inspection Service a feeling that, in many points, they sadly needed revision, and particularly in regard to the inspection of boiler material and the rules for permissible working pressure in boilers.

The form of test piece for boiler material was in use by no other public office or private corporation of any standing, and had been shown repeatedly by actual experiment to give fallacious results for the strength. In some cases the error was as great as twenty-five per cent., and the average error was probably not far from twenty per cent. Had this error consisted in showing too low a strength, it would at least have been on the safe side, and the only harm would have been that the boiler shells were unnecessarily thick. Unfortunately, the error was just the other way, making the shells too thin.

The rule for permissible working pressure was also radically defective in that, while ostensibly requiring a factor of safety of six, the real factor for first-class single riveting was only 3.36, and for the strongest double-riveting 3.75, with the presumption of a proper value for the ultimate tensile strength; but, as already remarked, the method of test gave a fictitious value for the tensile strength about twenty per cent. too great, so

that these values for the actual factor of safety should be reduced to 2.8 and 3.14 respectively. This would be bad enough, but the rule did not provide for taking account of the *actual* percentage strength of the longitudinal seams, and a double-riveted joint with a strength as low as fifty per cent. would be allowed, if the workmanship were first-class, the same value as a seventy-five per cent. joint. Elsewhere in the rules there is a provision that only first-class workmanship will be passed, but the work on a fifty per cent. joint might be perfect although the design is atrocious. Such a poor joint is rare, but, on a tug built under these rules and afterwards purchased for the Navy, the longitudinal joints have only sixty-six per cent. strength, due to improper spacing and too large rivets. Again, there was no provision of any kind recognizing the treble riveted joints, now so common.

It would be beyond the purpose of this introduction to analyze in detail all the points in which the existing rules were defective or failed to provide for modern progress. A comparison of the proposed rules as given hereafter with existing ones will show them, at least in the judgment of the writer.

The preparation of the Frye Bill was undertaken in consequence of the recommendation of the American delegates to the International Marine Conference that the existing Inspection Rules should be revised by experts, and new ones, if necessary, be formulated so as to cover all cases. In consequence of this recommendation, the Secretary of the Treasury was requested to convene a board of experts, and three deck officers of the Revenue Marine were by him constituted such board, and to them were referred the recommendations of the Marine Conference. Shortly after beginning their work they asked that an engineer officer be added to look after those portions of the rules relating to machinery and the examinations and qualifications of engineers. Chief Engineer John W. Collins, U. S. R. M., consulting engineer for the Revenue Marine, was so detailed, and at his suggestion the Treasury Department requested the Navy Department to detail an engineer officer of the Navy to

confer with and assist him. The writer was selected and ordered to perform this duty.

The two Government engineers thus detailed realized fully the great importance of the duty to be performed, and endeavored to profit by the best information attainable either at home or abroad. Believing that the rules of Lloyd's Register and the British Board of Trade, which govern such an enormous extent of machinery and are subject to such keen criticism, are worthy of most careful attention, they endeavored to test such rules as experience and the best advice at hand seemed to dictate by the rules of these two organizations. The result of their labors is shown by the sections of the Frye Bill relating to machinery and the engineering *personnel.*

Since the bill was printed and distributed, Senator Frye has received an immense number of comments, and while a few commend the intent of the bill, it may be said that practically all condemn the bill, and particularly the sections under consideration. Many of the condemnations are on the ground that, while changes are desirable, they should be in the form of regulations, subject to change by the Board of Supervising Inspectors, and not, as in the bill, in the form of law, which can only be altered by act of Congress. Many of them, however, condemn the proposed rules in themselves, say that existing rules are entirely satisfactory, and that no changes should be made.

The chief objection from everybody has been to sections 84 and 85, which provide that old boilers must, after the passage of the bill, be worked with a factor of safety of five, the same as new boilers. This is the only point upon which the writer desires to comment at this time, but he believes a few words will show the position of his colleague and himself. As already pointed out, they were well aware that boilers hitherto built had a much lower factor of safety, and that the proposed sections would scale down the working pressure by a considerable amount. They believed, however, that a factor of safety of five was as small as should be permitted in new boilers, and it seemed to them that, from an engineering standpoint, it would be absurd to recommend that old boilers, built under a less careful inspec-

tion, should have a lower factor. They recognized, however, that, as a matter of public policy, there are very strong arguments against the enactment of a law which would depreciate the value of property built in strict conformity with the existing law at the time. But this, in their opinion, was a matter for Congress to determine—not them—and they were convinced that, before the passage of the bill, it would receive the closest scrutiny of Senator Frye and his colleagues. This will undoubtedly be the case.

Although the engineers who prepared the sections of the bill under consideration have been criticized unmercifully both in the press and the letters sent to Senator Frye, the writer desires to refrain from any effort, at this time, to comment upon these criticisms or to reply to them. He cannot, however, omit all reference to the comments of the Board of Supervising Inspectors. These were prepared in the form of a letter to the Secretary of the Treasury, but copies were afterwards scattered broadcast over the country and formed the basis of most of the criticisms by organizations.

Now, this revision of the Steamboat Inspection Rules was not an attack upon the Board or any member, but the conscientious performance of duty in obedience to orders. It would have been expected, therefore, that changes which are merely recognition of the best practice of the best engineers all over the world would have been cordially approved. As a matter of fact, however, except in one unimportant matter, this Board condemned every change suggested.

In explanation of the introduction of the Bill before it had been sent for criticism to those most interested, it may be said that Senator Frye adopted this method as the surest for securing earnest and exhaustive comment. His expressed intention is, after all criticisms have come in, to return the bill to the framers for revision in view of these comments. Then the Committee on Commerce will itself make the final revision.

The writer would say that, with the consent of the Council of the Society, he cordially invites comment and criticism of the Bill from the many members and associates of the Society, whose

personal interest in the matters involved and great experience in marine machinery would make their remarks of the greatest value in the revision which the Bill is still to undergo.

The numbers to the paragraphs are those of the same sections in the Bill. The tyographical errors in the Bill have been rectified as here printed.

THE FRYE BILL.

"S. 1755.—In the Senate of the United States. January 20, 1892.

"Mr. Frye introduced the following Bill; which was read twice and referred to the Committee on Commerce:

"A Bill to amend certain sections of title fifty-two of the Revised Statutes of the United States and to carry into effect certain recommendations of the United States delegates to the International Marine Conference.

"*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,*

"SEC. 36. That before any material shall be passed for incorporation into marine boilers it shall be subjected to the inspection and tests hereinafter provided for by a duly authorized Government inspector. Plates shall be free from laminations, cracks, scabs, or any other defects tending to reduce their strength, and they must be of practically uniform thickness. All plates which show defects in these respects shall be rejected if, in the opinion of the inspector, the defects are of a nature sufficiently serious to reduce the strength of the plate more than five per centum.

"SEC. 37. That to ascertain the tensile strength, elongation, and other qualities of boiler material, there shall be taken from each plate which is to be tested two test pieces (cut from diagonally opposite corners), one for tensile test and one for quenching and bending test, as hereinafter described. The test pieces may be cut either longitudinally or transversely, that is, in the direction of rolling or across it. The skin of the test pieces shall not be removed by planing, shaping, or otherwise, the edges only being planed or shaped, and in no case shall test pieces be prepared or reduced in size by hammering or otherwise working on the anvil.

The piece for tensile test shall have a length of at least fourteen inches. It shall be two inches wide across the shoulders, which shall join, by an easy fillet, a parallel-sided portion with an uniform width for a length of eight inches. This reduced width shall be such that the cross section shall in no case be less than forty-five hundredths square inch for the thinnest plates nor less than fifty hundredths square inch for plates over three-eighths of an inch thick, provided, however, that for plates over three-eighths of an inch thick the width may be the same as the thickness, so that, in such specimens, the parallel portion will be of square section. The test piece thus prepared shall be subjected to tensile stress in a testing machine of approved pattern by gradually increasing loads until the piece is ruptured. The tensile strength will then be determined by dividing this breaking load by the original area of cross section, and this quotient will be the tensile strength per square inch. The tensile strength thus found must be for wrought iron from forty-five thousand to sixty thousand pounds per square inch, and for mild steel from fifty-eight thousand to sixty-seven thousand pounds per square inch. At the same time the elongation of an original length of eight inches, measured entirely in the reduced parallel portion, must be for wrought iron not less than fifteen per centum and for mild steel not less then twenty-five per centum. The test piece for the quenching and bending test shall not be less than two inches wide and about twelve inches long. The sides where sheared or planed must not be rounded, but the edges may have the sharpness taken off with a fine file. The test piece will be heated to a cherry red and then plunged into water at a temperature of about eighty degrees Fahrenheit. Thus prepared, it must be possible to bend the specimen double around a curve whose diameter is not more than once and a half the thickness of the specimen without its showing any cracks. The ends must be parallel after bending. This quenching test is to apply only to steel plates. For wrought-iron plates the specimen will be bent cold to an angle of ninety degrees around a curve whose radius is not more than once and a half the thickness of the plate and must not show any cracks or flaws.

"SEC. 38. That, if the inspection and tests hereinbefore specified shall show the material to be of good quality and the tensile strength up to the requirements, it shall be passed for incorporation into the shells of marine boilers, except where the sheets would form part of the heating surface. Should the tensile test show the strength to be less than that stamped on the plate or should the quenching or bending tests show that the material is not of good quality, the plate shall be rejected, provided, however, that if the plate is satisfactory in every other respect than the tensile strength, the manufacturer may restamp it with the value found by the inspector, and it shall then be passed for that strength, provided always, that the plate has not been used for any part of a boiler.

"SEC. 39. That, for plates intended for furnaces, fire boxes, or combustion chambers, or for shells of externally fired boilers, or such as have the shell forming part of the heating surface of the boiler, and for plates that are to be flanged, the tests and requirements shall be the same as already given for shell plates, except that steel plates shall have an ultimate tensile strength of from fifty thousand to fifty-eight thousand pounds per square inch and an elongation in eight inches of twenty-eight per centum.

"SEC. 40. That from and after the passage of this act no wrought-iron plate with a lower tensile strength than forty-five thousand pounds per square inch shall be allowed in any marine boiler, nor shall wrought iron be used in or about marine boilers when its thickness, as calculated under the requirements of the Revised Statutes of the United States, would be more than three-fourths of an inch; and no steel plate of a lower strength than fifty-eight thousand pounds per square inch shall be used for shells, except as provided below, nor of a lower tensile strength than fifty thousand pounds per square inch for plates forming part of the heating surface.

"SEC. 41. That every iron or steel plate intended for the construction of boilers to be used on steam vessels shall be stamped by the manufacturer in the following manner: At the diagonal corners, at a distance of about four inches from the edges, and

at or near the center of the plate, with the name of the manufacturer, the place where manufactured, and the number of pounds tensile strength it will bear to the sectional square inch and the percentage of elongation in eight inches.

"SEC. 42. That boiler makers shall inform the inspector of boilers in their district, by letter, when they have a new boiler to build, and furnish him with a tracing or blue print of the detail drawing of said boiler, and shall give him due notice when the plates will be ready for the test pieces to be cut from them. The inspector, when thus notified, shall examine the surfaces and edges of all plates to see if they are free from laminations, cracks, scabs, and other defects, as hereinbefore provided, and he shall then select at least one in four of these plates, to which he shall affix his private mark (for future identification), which mark shall also be placed on the test pieces before they are cut from the selected plates. The boiler-maker shall then prepare the test pieces in conformity with this act, and shall deliver them to the inspector when finished, together with an affidavit stating that the accompanying test pieces are the same as those marked by the inspector, giving name of firm or person by whom the plates were manufactured and locality of plant, with the lowest tensile strength and elongation stamped thereon, and that the plates from which these test pieces were cut are to be used in the construction of a marine boiler for (giving name of vessel); that no plate for shell or other part of this boiler will be used of less tensile strength, elongation or quality than herein specified. The affidavit shall also give the general dimensions and description of boiler. The inspector shall make his tests as soon afterwards as possible, and transmit a copy of the original test sheet in his office, together with a description of the plates that failed in tensile strength, elongation and quality of material to the Supervising Inspector General. The inspector shall also send a copy of the tests to the boiler maker, and state what plates failed to come up to the requirements. Should the tests herein specified show that the material is not of uniform quality or that the test pieces do not come up to the requirements, either in tensile strength, elongation or bending, the inspector shall have the right to call

for test pieces from every plate until he is thoroughly satisfied of the quality.

"SEC. 43. That boilers will be inspected at different stages of construction by the inspector, who shall carefully examine the design, material and workmanship, and shall have authority to reject any part that is not in conformity with this act or existing law. Before a boiler is used on board any vessel in the navigable waters of the United States, it shall be subjected to a hydrostatic test, such test to be made once every year thereafter in the following manner: The boiler shall be filled entirely full of water, a fire lighted in the furnaces, and the temperature of water brought to two hundred degrees Fahrenheit, when the said boiler shall be subjected to a hydrostatic pressure of one and a half times the working steam pressure allowed per square inch. In applying this test to boilers with steam chimneys, the test gauge shall be applied to the water line of such boilers. The inspector, after applying the hydrostatic test, shall go inside the boiler and make a thorough examination of every part of the same. If the test is not satisfactory, the defects must be made good and the boiler retested.

"SEC. 44. That where butt straps are used in the construction of marine boilers the straps for single butt strapping shall in no case be less than the thickness of the shell plates, and shall be on the outside, and where double butt straps are used the thickness of each shall in no case be less than five-eighths the thickness of the shell plates. Butt straps must be cut from plates, and not from bars, and must be of the same tensile strength and elongation as the plates used in shell, and for longitudinal seams must be cut across the fiber.

"SEC. 45. That before the work of laying out the rivet holes is begun, the boiler-maker shall submit to the inspector a drawing showing the kind of joint he intends to use, with details of pitch, diameter, spacing of rivets, thickness of butt straps. From this the inspector will determine the percentage strength of the joint, that is, the ratio of the strength of the joint to that of the solid plate, for use in determining the working pressure in the following 'Rule for Pressure Permissible in Marine Boilers,' pro-

vided that if the boiler maker so elects he need not submit this drawing until after the boiler is built, but, in that case he must accept the factor for strength of joint determined by the inspector and the working pressure determined in consequence.

"SEC. 46. That from each one hundred rivets the inspector will select two, which shall be subjected to the following tests: One shall be flattened out cold under the hammer to a thickness of one-half the diameter without showing cracks or flaws; the other shall be flattened out hot under the hammer to a thickness of one-third the diameter without showing cracks or flaws, the heat to be the working heat when driven. The inspector is also authorized to make such additional tests as in his judgment may be necessary to determine the quality of the material; and if the rivets are of steel he shall subject at least one of the specimen rivets to a quenching test to insure that the material can not harden.

"SEC. 47. *Rule for Pressure Permissible in Marine Boilers.*—That the pressure for any boiler with a cylindrical shell to be used on vessels licensed by the United States shall be determined by the following rule: Multiply one-fifth of the lowest tensile strength found stamped on any plate of the cylindrical shell by the fraction which expresses the ratio of the strength of the longitudinal riveted joints to that of the solid plate; then multiply this product by the thickness, expressed in inches and parts of inches, of the thinnest plate in the same cylindrical shell, and divide by the radius or half diameter, also expressed in inches, and the quotient will be the pressure allowable per square inch, provided that all other parts of the boiler shall correspond in strength to that of the shell, and that in no case shall the working strength of any material be taken higher than one-fifth of the ultimate strength.

"The foregoing rule applies to the best material, with all the rivet holes drilled and edges planed. If the rivet holes be punched, the edges sheared, or the workmanship defective, the factor of safety shall be increased by the inspector. The reamer, and not the driftpin, must be used to enlarge the holes, and the

burr must be taken off the edges before the plates are riveted together.

"SEC. 48. That where flat surfaces exist, the inspector must satisfy himself that the spacing and distance apart of the bracing and all other parts of the boiler are so arranged that all shall be of not less strength than the shell.

"SEC. 49. That the strength of stays supporting flat surfaces shall be calculated from the smallest part of the stay or fastening; the strain upon them is not to exceed the following limits, namely: *Iron Stays:* For screw stays and for other stays not exceeding one and one-half inches effective diameter, and for all stays which are welded, six thousand pounds per square inch. For unwelded stays above one and one-half inches effective diameter, seven thousand five hundred pounds per square inch. *Steel Stays:* For screw stays and for other stays not exceeding one and one-half inches effective diameter, eight thousand pounds per square inch; for stays above one and one-half inches effective diameter, nine thousand pounds per square inch. No steel stays are to be welded. Where screw stays are used, the holes in the two sheets must be tapped in the same operation, so that the thread is continuous, and, where the sheets slope so that the stays do not come square with the sheet, beveled washers will be used, on which the nuts will be set up.

"SEC. 50. That the strength of flat plates supported by stays shall be taken from the following formula:

$$\frac{C \times T^2}{P^2} = \text{working pressure in pounds per square inch.}$$

Where T = thickness of plate in sixteenths of an inch (expressed as a whole number, *i. e.*, $\frac{3}{4}'' = 12$).

P = greatest pitch in inches.

C = 90 for plates $\frac{7}{16}$ thick and below fitted with screw stays with riveted heads.

C = 100 for plates above $\frac{7}{16}$ fitted with screw stays with riveted heads.

C = 110 for plates $\frac{7}{16}$ thick and under fitted with screw stays and nuts.

$C = 120$ for plates above $\frac{7}{16}$ fitted with screw stays and nuts.

$C = 140$ for plates fitted with stays with double nuts.

$C = 160$ for plates fitted with stays with double nuts and washers at least $\frac{1}{2}$ thickness of plates and a diameter of $\frac{2}{5}$ of the pitch, riveted to the plates.

"SEC. 51. That in the case of front plates of boilers in the steam space, these numbers shall be reduced twenty per centum, unless the plates are guarded from the direct action of the heat. If it is desired to secure a wider spacing of stays or braces than would be allowed by the above formulæ, by the use of T-bars or double angles, permission may be secured from the supervising inspector when the drawing of the boiler is submitted for his examination.

"SEC. 52. *Girders.*—The strength of girders supporting the tops of combustion chambers and other flat surfaces is to be taken from the following formula:

$$\frac{C \times d^2 \times T}{(L - P) \times D \times L} = \text{working pressure in pounds per square inch.}$$

Where L = length of girder.

P = pitch of stays.

D = distance apart of girders.

d = depth of girder at center.

T = thickness of girder at center. All these dimensions to be taken in inches.

$C =$ { 6,000 if there is one stay to each girder.
9,000 if there are two or three stays to each girder.
10,200 if there are four stays to each girder.

"SEC. 53. That in determining the working pressure allowable in shell boilers that are not cylindrical, the rules already given for strength of braced surfaces will be followed, and special care will be taken that in crow-foot and palm braces the branch braces, palms, pins, and rivets are all so proportioned that the strength shall nowhere be less than that of the main

part of brace where it has the least cross section. The material shall be tested as already directed.

"SEC. 54. That in the case of boilers of the coil, tubulous or sectional type, the strength of the various parts shall be calculated by the rules already given applicable to such cases. For the cylindrical portions where not unduly weakened by numerous tube holes, a factor of safety of five may be allowed where the workmanship is of the best, but the inspector may increase it if in his judgment necessary. The tubes for such boilers shall be subjected to hydrostatic pressure of five hundred pounds by sample, so as to satisfy the inspector that they are amply strong and well made.

"SEC. 55. That the allowable working pressure for flues, subjected to an external collapsing pressure, shall be determined by the following rules: For plain cylindrical flues, either lapwelded or butted and strapped so that the form is that of a true cylinder:

$$P = \frac{90{,}000 \times t^2}{L \times D}.$$

Where t = thickness of metal in inches.

L = length of flue or length between strengthening rings, in feet.

D = external diameter in inches.

In no case, however, shall the working pressure exceed

$$\frac{8{,}000 \times t}{D}.$$

"SEC. 56. That if the longitudinal joints, instead of being lapwelded or butted, are lapped and riveted, then seventy thousand shall be used for the constant instead of ninety thousand, unless the lap is beveled and so made as to give the flue a true circular form, in which case eighty thousand shall be used for the constant.

"SEC. 57. That when the material or the workmanship is not of the best quality, the constants given above must be reduced; that is to say, the ninety thousand will become eighty thousand, the eighty thousand will become seventy thousand, the seventy thousand will become sixty thousand; and when neither the material nor the workmanship is of the best quality, such con-

stants will require to be further reduced, according to circumstances and the judgment of the inspector, as in the case of old boilers. One of the conditions of best workmanship must be that the joints are either double riveted with single butt straps or single riveted with double butt straps, and the holes drilled after the bending is done and when in place, and afterwards taken apart, the burr on the holes taken off and the holes slightly countersunk from the outside.

"SEC. 58. *Corrugated Furnace Flues.*—That when the furnace flue is truly cylindrical in every cross section and the plain part does not exceed six inches in length, the working pressure must not exceed $\frac{* 12{,}500 \times t}{D}$, where D is the mean external diameter. In no case shall the thickness be less than five-sixteenths inch.

"SEC. 59. *Ribbed Furnace Flues.*—That where the plain part does not exceed nine inches between ribs and the ribs are at least one and three-eighths inches above plain part, the working pressure shall not exceed $\frac{14{,}000 \times t}{D}$, where D is the external diameter of plain part.

"SEC. 60. That if any forms of flues not covered by the foregoing rules are submitted they will be referred to the Supervising Inspector General for decision.

"SEC. 61. That if the flues are fitted with strengthening rings, a drawing showing the proposed method must be submitted to the inspector for approval before work is begun. Care must be taken, if an angle iron is used, that it is set off far enough from the flue to permit of proper circulation of water, and that the spacing of socket rivets is not so close as to reduce the strength of the flue.

"SEC. 62. That the boilers of foreign-built ships which have acquired a United States register shall be subject to the same inspection in all respects as those built in the United States.

"SEC. 63. That in determining the allowable working pressure

* When the bill is revised the 12,500 will be changed to 14,000, in accordance with the result of the experiments given elsewhere in this number of the JOURNAL.—EDITOR.

the inspector shall be authorized to drill holes in any part for ascertaining the actual thickness. To determine the tensile strength of the plates the owners shall be called upon to produce a certificate of inspection from a recognized government department of the country where last owned or from a recognized underwriters' society, in either case having rules which specify the limits of tensile strength allowed for the material of which the boilers are built.

"SEC. 64. That if such a certificate is produced bearing date within a year of the first United States inspection then the United States inspector shall take as the strength of the plate when new the lower limit allowed by the department or society whose certificate is exhibited. If no such certificate is shown, the inspector shall assume a strength when new of forty thousand pounds per square inch for wrought-iron plates and fifty thousand for steel plates.

"SEC. 65. That in determining the working pressure the inspector thall take into consideration the age and condition of the boiler, as well as the thickness, original strength, efficiency of riveted joints, and proper factor of safety. In no case shall a factor of safety less than five be allowed.

"SEC. 66. That on all boilers hereafter built a composition valve or cock shall be placed in the feed pipe between the check valve and the boiler, so as to permit of overhauling the check valve if necessary while steam is up.

"SEC. 67. That on all boilers hereafter built manholes shall be provided with strengthening rings of the same thickness as the sheet and riveted to it; the area of metal in the ring shall be equal to that of the hole. This rule shall also apply to all other openings in the boiler over six inches in diameter, except such as are covered by valve casings which have flanges of adequate size attached by tight-fitting bolts, *provided* that where it is preferred to secure the manhole plate by a frame going all around the opening instead of by 'dogs,' the strengthening ring may be omitted if the inspector is satisfied with the proportions of the parts.

"SEC. 68. That in the attachment of pipes and fittings to

boilers, no pipe, nipple, or fitting over one inch in external diameter shall be screwed into the boiler plates, and not then unless the plates are one-half inch thick and over. All fittings over one inch in external diameter shall be attached by suitable flanges and bolts.

"SEC. 69. That provision shall be made by a suitable feed-water heater or otherwise, as may be approved, that the feed water for boilers used with non-condensing engines shall have a temperature of at least one hundred and eighty degrees Fahrenheit.

"SEC. 70. That provision must also be made with every boiler or set of boilers for an adequate auxiliary feed with independent feed pipe and check valve, which, in case of accident to the main feed, shall be able to supply all the boilers when working at full power.

"SEC. 71. That vertical tubular boilers shall not be used on steamers navigating the Red River of the North and rivers whose waters flow into the Gulf of Mexico, unless the water line is two inches above the upper end of the tubes and fire line.

"SEC. 72. That in all steam vessels there shall be at least six inches clear space between the sides of the boilers and the nearest woodwork, and four inches between the top and the nearest woodwork, and there shall be at least eight inches between the under side of cylindrical shell and the floors or keelsons.

"SEC. 73. That in boilers which have no bottoms to the furnaces suitable provisions shall be made for an ash pan, to rest on fire brick laid in cement, to prevent damage by fire.

"SEC. 74. That where the 'connection' leading to uptake and chimney does not come in the fire room sufficient space must be allowed for opening the connection door to its full extent and for the withdrawal and replacing of tubes. If desired, this may be arranged by making recesses in the bulkhead opposite the 'connection.'

"SEC. 75. That slip joints in steam pipes of steamers running in salt water shall have all their working parts of copper or com-

position. In all such joints stop bolts shall be fitted to prevent the separation of the pipes.

"SEC. 76. That steam and exhaust pipes, where passing through bunkers or cargo spaces, shall be properly cased in, so that they can not be injured.

"SEC. 77. That in iron and steel vessels, the pipes leading through the bilge, if of copper, shall be placed high enough to be out of the bilge water under ordinary circumstances. The lower parts of bilge suction pipes shall be of galvanized iron.

"SEC. 78. That there shall be fastened to each boiler a plate containing the name of the manufacturer of the material, the place where manufactured, the tensile strength, the name of the builder of the boiler, when and where built.

SEC. 79. That every seagoing steamer of one thousand tons burden and upwards, built after the passage of this act and carrying passengers, shall be supplied with an auxiliary or donkey boiler of sufficient capacity to work the fire and and bilge pumps at their maximum rated capacity. This boiler shall be placed high enough in the ship to continue to work even though the main boiler compartments are flooded.

"SEC. 80. That every boiler subject to inspection under this act shall have inserted in the highest part of the heating surface a fusible plug of pattern approved by the Supervising Inspector General. The fusible metal shall have a melting point not higher than five hundred degrees Fahrenheit, and must be so fitted that the plug may be replaced by a new one (after the fusible metal has melted) with facility. The inspector shall have the right to decide at what point in the heating surface the plug shall be fitted.

"SEC. 81. That every boiler subject to inspection under this act shall have at least three gauge cocks and a glass water gauge, of patterns approved by the Supervising Inspector General. Each gauge cock shall attach directly to the boiler except in special forms where this is impossible, and in such cases the matter must be referred to the Supervising Inspector General for decision, who will direct how the gauge cocks shall be fitted, but he shall require the connection of the standard containing the

gauge cocks to the boiler to be by pipes of ample size, so that there shall be no possibility of their clogging. The gauge cocks shall be so placed that the lowest shall be at least an inch above the highest heating surface, the middle one about two inches below the ordinary water level, and the highest about six inches above the ordinary water level. The glass gauge shall have an exposed length of at least twelve inches and the lowest visible portion shall be at least one inch above the highest heating surface. The glass tube and the pipes connecting to the boiler must be of ample size, and the whole must be of the automatic self-closing pattern, so that when the glass breaks there shall be no danger of scalding the people in the fire room.

"SEC. 82. That the use of steam gauges heretofore passed by the inspector shall be permitted to continue if they are in good condition, but the inspector will note when applying the hydrostatic pressure whether they are correct or not. If not they must be properly adjusted. Before any new form of gauge is used, it must be submitted to the Supervising Inspector General and be authorized by him. All boilers or sets of boilers shall have attached to them at least one gauge that will correctly indicate a pressure of steam equal to eighty per centum of the hydrostatic pressure applied by the inspectors.

"SEC. 83. That the appliances in use on steamers constructed prior to the twenty-eighth of February, eighteen hundred and seventy-two, for determining the height of water in the boilers shall be considered reliable low-water gauges. There must be means provided, in all boilers using the 'low-water gauges' which are operated by means of a float inside the same, to prevent the float from getting into the steam pipe, in case of detachment. All horizontal cylindrical boilers used on steamers navigating the waters flowing into the Gulf of Mexico shall be provided with reliable low-water gauges.

"SEC. 84. That the boilers of all towing freight boats on the Mississippi River and its tributaries shall after the passage of this act be subject to the same inspection and tests as all other boilers under this act. Boilers built hitherto shall be inspected and tested and allowed a working pressure as hitherto provided

except that the factor of safety for the boiler shall not be less than five.

"SEC. 85. That all boilers on steam vessels which were built in conformity to existing law at the time and have since been regularly inspected shall be passed for use, provided always that the safe working pressure shall be determined as herein provided and that in no case shall a factor of safety less than five be allowed.

"SEC. 86. That where practicable sea valves and cocks shall be so bolted to bottom or bilge of hull that the joint is accesible at all times in order to notice if there is any leakage. Where fitted to vessels running in salt water, the valves, seats, stems, and bolts of sea cocks and valves shall be of composition.

"SEC. 87. That from and after the passage of this act all boilers subject to inspection under the provisions of this act shall be fitted with safety valves as follows: Every boiler shall have at least one spring-loaded safety valve of a pattern approved by the Supervising Inspector General. Such valves must be so made that when opened they offer additional surface to the escaping steam, thus insuring an adequate exit for the steam. The valve face and seat must be of noncorrodible metal. The spring must be protected from the escaping steam. Provision must be made to prevent the valve from flying off in case the spring breaks. The valve and spring must be so incased that, when locked up by the inspector, it will be impossible to raise the pressure at which the valve will lift, though it may be lowered. There must be provision for opening the valve by hand, and, if there are several valves on a boiler, the hand lifting gear must raise them in succession. The valve chamber must be directly bolted to the boiler shell. The compressing screws must set up on metal stops or washers when the spring is set at the desired pressure. There must be enough coils in the spring to permit the valve to rise with the blowing-off pressure at least one-fourth of the diameter of the valve. Suitable drain pipes must be fitted, to free the valve chamber of water. In no case shall a valve less than two inches in diameter be fitted, and if the

necessary area would require a single valve over six inches in diameter, then two or more valves shall be fitted.

"SEC. 88. That the requisite valve area shall be determined by the following rules: First. When the coal is burned by natural draft with a chimney not over fifty feet above the grates: For a steam pressure of twenty-five pounds per square inch, one square inch per square foot of grate; for fifty pounds, fifty-eight hundredths square inch per square foot of grate; for one hundred pounds, thirty-three hundredths square inch per square foot of grate; for two hundred pounds, seventeen and one-half hundredths square inch per square foot of grate. For intermediate pressures the area of the valve will be diminished for each ten pounds increase of pressure as follows: Between twenty-five and fifty pounds, sixteen hundredths square inch; between fifty and one hundred pounds, five hundredths square inch; between one hundred and one hundred and fifty pounds, two hundredths square inch; between one hundred and fifty and two hundred pounds, one hundredth square inch. Second. For forced draft or natural draft with a chimney exceeding fifty feet in height above the grate. The intended air pressure or height of chimney, together with the estimated combustion of coal per square foot of grate surface, will be submitted to the supervising inspector, who will direct what shall be the area of the valve. In reaching a decision he will be governed by the following table, showing the discharge of steam of various pressures through a simple opening with an area of one square inch:

Steam pressure per square inch above atmosphere.	Weight of steam discharged per minute in pounds through a plain opening with an area of one square inch.
20	31.00
30	39.50
40	48.00
50	56.50
75	77.75
100	98.90
150	141.10
200	183.50

"Owing to the increase of resistance to exit in a valve under actual conditions it will be assumed, in fixing the valve area, that a square inch of opening of valve is only equal to one-tenth of a square inch of the plain opening.

"SEC. 89. That in the annual inspection of machinery provided for in section forty-four hundred and eighteen, Revised Statutes, special attention will be paid to the safety valves to see that they are in a state of the highest efficiency.

"SEC. 90. That the feathers for guiding the valve must have enough clearance to insure that they shall not bind under any circumstances. The pin in fulcrum of hand tripping gear, if not made of brass, must be bushed with brass, and the lever must be so arranged that, even if it sticks, the valve will be perfectly free to open under steam pressure.

"SEC. 91. That it shall be the duty of the engineer in charge to blow or cause to blow at least once in each watch of six hours or less the lock-up safety valves on the boilers to insure their readiness for use. Should this test show them not to be working properly, the fact shall be reported to the local inspector at the earliest opportunity.

"SEC. 92. That in case no such report has been made, and a safety valve is found that has been tampered with or is out of order, the certificate of the engineer who is responsible therefor shall be revoked.

"SEC. 93. That the spring-loaded valve or valves shall be fitted in a case with suitable lock and key, the latter of which shall be kept by the inspector after he has set the valve at the proper blowing-off pressure.

"SEC. 94. That besides the lock-up safety valve hereinbefore specified, every boiler shall have an additional safety valve, which shall be under the control of the engineer of the vessel. It may be of any pattern approved by the Supervising Inspector General, provided that, if not fitted with an appliance for increasing the surface exposed to pressure when the valve lifts, the area shall be increased as directed by the inspector. These additional valves shall all be fitted so that they can be lifted by hand from the fire room or other convenient place when necessary.

"SEC. 95. That all vessels whose machinery is subject to inspection under this act shall have their main engine shafting of at least the dimensions given by the following formula and table:

$$S = \sqrt[3]{\frac{C \times P \times D^2}{K\left(2 + \frac{D^2}{d^2}\right)}}.$$

Where S = diameter of shaft in inches;

d^2 = square of diameter of high pressure cylinder in inches, or the sum of the squares of diameters where there are two or more high-pressure cylinders;

D^2 = square of diameter of low-pressure cylinder in inches, or the sum of the squares of diameters where there are two or more low-pressure cylinders;

P = absolute pressure at engine, that is, gauge pressure plus 15 pounds;

C = length of crank in inches;

K = a constant from the following table:

Values of K.

Two cranks, angles between crank.	Crank and propeller shafts.	Intermediate shafts.
90 degrees.	1,050	1,220
135 "	800	935
180 "	740	860
3 cranks, 120 degrees.	1,110	1,295

"SEC. 96. That this formula and table are for screw engines only, and are for the ordinary case of double cranks to each cylinder with bearings of suitable dimensions on each side. Paddle steamers navigating only rivers, inclosed bays, or well-frequented lines of travel will not be subject to this rule. Paddle steamers

intended for sea service must have the dimensions of their shafts approved by the supervising inspector before building. The formula and constants apply to triple and quadruple expansion engines as well as to compound engines. They do not apply to simple engines, and if any such are to be licensed the proposed size of shafts must be submitted to the supervising inspector before building.

"SEC. 97. That all passenger steamers engaged in foreign traffic on the ocean and whose length of route exceeds one thousand miles shall carry at least the following spare parts and stores; the spare parts must have been fitted in place or the inspector must be satisfied that they are of suitable dimensions:

"One set of valves (if of rubber) for each size of pump, including air, circulating, feed, and auxiliary pumps; if metal valves are used, then one spare valve and spring of each size.

"One-half set of follower bolts for each size of piston of main engines and of air and circulating pump engine if independent.

"One-half set of springs for each piston of main engines and of air and circulating pump engines if independent.

"One set of main journal brasses.

"One set of crank-pin brasses for main engines.

"One set of brasses for crosshead pins of main engines.

"One set of connecting-rod bolts for main engines and for air and circulating pump engines if independent.

"One set of main bearing cap bolts.

"One set of shaft-coupling bolts.

"One section of crank shaft, if made in more than one section.

"Two propeller blades, fitted to hub, when of built-up type.

"One set of brasses for valve gear of main engines and of air and circulating pump engines if independent.

"One piston rod for each air and circulating pump if independent.

"One check valve and one bottom blow valve of the size fitted to boilers.

*"One set of boiler water-gauge glasses.

**"One spring of each size for cylinder water valves.

*"One spring for every four safety valves, and at least one in any case.

"Fifty condenser tubes, with glands and packing complete.

"Three boiler tubes for each boiler.

*"Ten per centum of total number of grate bars necessary.

*"One set of taps and dies up to two inches diameter.

*"An anvil and a set of smith's tools, including portable forge.

*"A bench vise of fair size and an outfit of bench tools to do ordinary work.

*"A set of ratchet drills, with suitable braces and standard.

*"A set of expanding tools for boiler tubes.

*"An assortment of brass and iron bolts and nuts threaded and ready for use.

*"An assortment of bar and sheet iron suitable for repair work.

*"One screw jack and one hydraulic jack to lift ten tons.

"Vessels engaged in coastwise trade and vessels in foreign trade on the ocean where the length of route is less than one thousand miles will be required to carry only the articles marked thus:*

"SEC. 129. That the minimum complement of engineers for vessels licensed for carrying passengers shall be as follows: Seagoing steamers: Twin-screw steamers with machinery of over ten thousand indicated horse power, one chief engineer of the highest grade and nine assistant engineers, of whom at least three shall hold certificates as first assistants and three as second assistants.

"SEC. 130. Twin-screw steamers with machinery from five thousand to ten thousand indicated horse power, one chief engineer of the grade from five thousand to ten thousand indicated horse power and nine assistants, of whom at least three shall hold certificates as first assistants and three as second assistants.

"SEC. 131. Single-screw steamers with machinery of over ten thousand indicated horse power, one chief engineer of the highest grade and six assistants, of whom at least three shall hold certificates as first assistants and two as second assistants.

"SEC. 132. Single-screw steamers with machinery of from five thousand to ten thousand indicated horse power, one chief engineer of the grade from five thousand to ten thousand indicated horse power and five assistants, of whom at least three shall hold certificates as first assistant, and one as second assistant.

"SEC. 133. Single-screw steamers with machinery of from two thousand to five thousand indicated horse power, one chief engineer of the grade and five assistants, if there are many auxiliaries independent of the main engines; if there are very few auxiliaries, three assistants. In the first case, at least three of the assistants shall hold certificates as first assistant, and one as second assistant; in the second case, two shall be first assistants and one second assistant.

"SEC. 134. Single-screw steamers with machinery of less than two thousand indicated horse power, one chief engineer of the grade except as provided for the cases where first and second assistants may be in charge, and two assistants, of whom one shall be a first assistant.

"SEC. 135. Paddle-wheel steamers, one chief engineer of grade according to horse power and two to five assistants, depending on number of auxiliaries. If there are five assistants, three shall hold certificates as first assistant and one as second assistant; if there are less than five assistants, at least one shall hold a certificate as first and one as second assistant.

"SEC. 136. Steamers navigating lakes, bays, sounds, and rivers: There shall in every case be a chief engineer of the grade corresponding to the horse power, except, as elsewhere provided, when first and second assistants are allowed in charge, and a number of assistants depending on the size and complexity of the machinery and the duration of the trip between terminals; but in no case shall any steamer on routes of longer than fourteen hours' duration be allowed to run with less than two engineers, including the chief engineer, and when there is only one assistant he shall hold a certificate at least as high as second assistant, provided that in the case of small pleasure steamers of ten tons and under a third assistant engineer may have charge of the machinery.

"SEC. 137. That in every steamer engineers holding a certificate of higher grade than that required may perform the duties of the lower grade.

"SEC. 138. That before a steamer is licensed for carrying passengers the supervising inspector of the district must be notified of the service she is intended to perform, and he shall make a personal inspection of the machinery and decide upon the minimum complement of engineers in those cases where it is not specifically provided for. In his decision he will be governed by the arrangement and complexity of the machinery, the subdivision by water-tight bulkheads, and all other matters which increase the difficulty of properly caring for the machinery.

"SEC. 139. That in all cases, including those specifically provided for, he is authorized to increase the complement if, in his judgment, the complexity and arrangement of the machinery, the number of auxiliaries and the arrangement of bulkheads make it necessary to the adequate care and supervision of the machinery while in operation. Should the owner of the steamer deem the number assigned too great he may appeal to the Supervising Inspector General, transmitting plans of the vessel and machinery in sufficient detail to enable an intelligent decision to be rendered.

"SEC. 140. That, in the case of steamers used entirely as freight carriers and not carrying passengers, the number of engineers shall be decided by the supervising inspector after a personal inspection and knowledge of the intended service.

"SEC. 141. That in all cases there shall be a chief engineer of the appropriate grade, except as elsewhere provided, when first and second assistants are allowed in charge.

"SEC. 142. That, if the vessel is a seagoing one and the duration of the voyage is more than forty-eight hours, there shall always be at least three engineers, including the chief, and one of the assistants must hold a certificate as first assistant. If the voyage lasts less than forty-eight hours there may be two engineers only, provided that the vessel remains in port between trips at least twenty-four hours.

"SEC. 143. That if the vessel does not go to sea, but navigates

only bays, sounds, lakes and rivers, there must be two engineers if the average number of hours under way per day exceeds ten, or if the number of hours for any single regular run exceeds twelve. Where the duration of the trip is less than herein specified one engineer only will be required.

"SEC. 144. That in the case of pile drivers, sawmill boats and other small craft, not carrying passengers, a third assistant engineer may have charge of the machinery if it does not exceed one hundred indicated horse power. That a special certificate may be granted authorizing the holder to act as engineer on steamers of ten tons and under, not carrying passengers or freight for pay, if the local inspectors are satisfied that the candidate is competent.

"SEC. 145. That the classification of engineers in the merchant service of the United States shall be as follows: Chief engineer of machinery exceeding ten thousand indicated horse power, chief engineer of machinery between five thousand and ten thousand indicated horse power, chief engineer of machinery between two thousand and five thousand indicated horse power, chief engineer of machinery of two thousand indicated horse power and less, first assistant engineer, second assistant engineer, third assistant engineer.

"SEC. 146. That first assistant engineers may act as chief engineers of engines of less than three hundred indicated horse power, and second assistant engineers may have charge of engines of less than one hundred indicated horse power, provided the vessel in which such engines are placed is used in river or harbor service only or does not go to sea beyond twenty miles.

"SEC. 147. That a chief engineer for engines of ten thousand indicated horse power and upward must be at least thirty years old and must have served at least five years at sea as a chief engineer or first assistant with engines of over two thousand indicated horse power. He must be able to superintend the construction of machinery for two thousand indicated horse power and upward, and to devise and direct the repair of any accident to the machinery likely to occur. He must be able to secure a general average of ninety per centum on the examina-

tion for chief engineer hereinafter provided for, and an average of seventy-five per centum on such additional questions as may be given by the examining board for this grade and the next lower.

"SEC. 148. That the requirements for a chief engineer for machinery of from five thousand to ten thousand indicated horse power shall be the same as for a chief engineer for machinery of over ten thousand indicated horse power, except that he shall only be required to secure an average of eighty per centum on the general examination for chief engineer and seventy per centum on the special questions for this grade and the next higher.

"SEC. 149. That a chief engineer for machinery of from two thousand to five thousand indicated horse power must be at least thirty years of age and have served at least five years as chief engineer of a seagoing steamer, or as first assistant with engines from two thousand to five thousand indicated horse power. He must be able himself to do or direct the adjustment of any part of the engines, and to run the lines for them and erect them in the vessel. He must be conversant with work on boilers and piping, and able to direct the repair of any accident to them, as well as the accidents likely to occur to the engines. He must secure seventy-five per centum on the general examination for chief engineer.

"SEC. 150. That a chief engineer for machinery of two thousand indicated horse power or less must be at least thirty years of age, and must have served at least five years as a first assistant, or three years as a first assistant with engines of two thousand indicated horse power and over in a seagoing ship. He must be able to make himself or to direct the making of any ordinary repairs to any part of the machinery. He must secure sixty-five per centum on the general examination for chief engineer.

"SEC. 151. That a first assistant engineer must be at least twenty-five years of age, and must have served at least two years as a second assistant. He must understand the working of every part of the machinery and be able himself to make the adjustment directed by the chief engineer. He must understand the

use of all the mechanics' tools employed in work about marine machinery, and be himself skillful at some trade connected with the making or fitting of such machinery. He must secure at least sixty-five per centum on the examination for his grade.

"SEC. 152. That a second assistant engineer must be at least twenty-three years of age, and must have served at least one year as a third assistant. He must understand the working of marine machinery and be able to start, stop, and care for it while in motion. He must understand the usual remedies for such things as heated journals, low water, and foaming, and be able to fit and adjust bearings, pack stuffing boxes, and do other ordinary work about marine machinery. He must be proficient in some trade connected with the building of marine machinery. He must secure at least sixty-five per centum on the examination for his grade.

"SEC. 153. That a third assistant engineer must be at least twenty-one years of age. He must either be a machinist by trade, and have had at least one year's experience with engines and boilers on a vessel or on shore; or be a journeyman mechanic in a trade connected with the building of marine machinery, and have had one year's experience in the engine department of a steam vessel, or two years' experience with engine and boiler on shore; or have had at least three years' experience in the engine department of a steam vessel. He must secure at least sixty-five per centum at the examination for his grade.

"SEC. 154. That the examinations for the two higher grades of chief engineer shall be held by a board consisting of the supervising inspector of the district and two local inspectors of boilers, and shall take place not oftener than twice a year, and only then if there are applicants. The examination for the other two grades of chief engineer shall be held by a board of three local inspectors of boilers. These shall be held at least twice a year, and once a quarter if there are more than five applicants.

"SEC. 155. The examination for first, second, and third assistant engineers shall be conducted by the local inspector of boilers at least once each quarter if there are applicants.

"SEC. 156. That when an applicant for any of the grades of

engineers hereinbefore enumerated has not had the service in the merchant marine of the United States contemplated, but has had equivalent service with marine machinery elsewhere, of which he can produce satisfactory evidence, he shall be admitted to examination, and, if found to be possessed of the requisite degree of proficiency, shall be certificated the same as if his previous service had been in the merchant marine of the United States.

"SEC. 157. That applicants for every grade of engineer must satisfy the examining board that they are of sober and correct habits; and, if called upon by the examining board to do so, must furnish the names of the vessels on which they have previously served, together with the names of the masters and chief engineers, to whom the board may address interrogatories if they deem it necessary to establish the character of the applicant. If the service has been on shore the testimonials must be signed by an employer.

"SEC. 158. That nothing contained in the foregoing rules is to be construed to deprive any engineer of the certificate which he now holds or of the privilege of renewal in accordance with the rules heretofore existing, except as hereinafter provided.

"SEC. 159. That, if an engineer with a certificate desires to qualify for duty with machinery of greater horse power than that of the class with which he is serving, he must make application and pass the examination provided for above for such higher class of machinery, and this is to apply to the various grades of assistants as well as to those of chief; that is, an engineer may continue to hold his certificate for the same kind and power of machinery, but if he desires to serve with larger or different machinery he must pass the examination for the grade he desires to hold, as herein provided.

"SEC. 163. That the qualifications required for the several grades below mentioned shall be as follows:

"*Third assistant engineer:*

"First. He must know the names of the different parts of a steam engine and boiler and of the fittings and mountings, including condenser and pumps.

"Second. He must be able to lay and start fires and raise steam and understand the precautions to be taken to prevent injury to the boiler; must know how to 'tend water,' fire, and clean fires; also what to do in case of low water.

"Third. He must be able to start, stop and reverse the engine, and know what precautions to observe in starting to prevent injury to engines and boilers.

"Fourth. He must know what to do to engines and boilers in case of foaming, and course to be pursued in the case of hot bearings.

"Fifth. He must be able to read the steam and vacuum gauges and other instruments about the machinery intelligently.

"Sixth. He must know the first four rules of arithmetic and be able to write a legible hand.

"SEC. 164. *Second assistant engineer:*

"First. He must be able to give a description of the boilers and engines in common use on board ship and of the fittings and connections used with them, including the way in which boilers are braced, and the use and management of the different valves, cocks, levers, and so forth.

"Second. He must be able to tell how ordinary repairs to boilers are made, such as hard and soft patching, riveting, expanding tubes, calking seams, plugging leaky tubes, and so forth.

"Third. He must understand the use of the thermometer, barometer, salinometer, steam and vacuum gauges, gauge cocks, and glass water gauges, and in general all other fittings about the machinery.

"Fourth. He must be able to tell what foaming and priming are, how discovered, and their effects on boilers and engines, and what is done to stop them.

"Fifth. He must be able to tell the course to be pursued in raising steam and getting engines and boilers ready for work, and the process followed when the machinery is no longer needed on reaching port, including both the cases when the fires are to be banked and when the boilers will not be needed for several days.

"Sixth. He must be able to tell how to ascertain whether the

journals are working properly and what to do to prevent heating, and to remedy it if it does occur.

"Seventh. He must be able to tell how firing should be conducted and how a fire should be cleaned.

"Eighth. He must be able to tell what to do in case of low water.

"Ninth. He must be able to tell how to lay up packing and how to pack stuffing boxes, pump pistons, and so forth.

"Tenth. He must know enough arithmetic to be able to work any problem under the fundamental rules and common fractions. He must be able to write a legible hand and write an ordinary letter so as to show a fair knowledge of spelling and grammar.

"SEC. 165. *First assistant engineer:*

"First. Familiarity with all the ordinary types of engines and boilers; explanation of the different parts, their object, and method of working.

"Second. Duties in raising steam and getting under way; in maintaining a good performance while under way; and when ship is anchored or secured.

"Third. Description of common derangements that may happen, such as foaming, hot journals, and so forth, with account of procedure to remedy them; also tell what should be done to prevent them.

"Fourth. Repairs: Tell how patches are put on boiler, tube expanded, and so forth.

"Fifth. Adjustment of journals and valve gear; setting of valves.

"Sixth. Using of steam-engine indicator and explanation of diagrams taken with it, as well as calculation of indicated horse power from diagram.

"Seventh. Expansion of steam; object of; how accomplished in practice.

"Eighth. Familiarity with instruments used about machinery, steam and vacuum gauges, thermometer, barometer, and so forth; how they should be fitted to insure accurate readings.

"Ninth. Fittings and mountings of engines, boilers, and auxil-

iaries; description of safety valves, safety-feed arrangements, gauge cocks, and glass gauges on boilers, and so forth.

"Tenth. Description of the steam pumps in common use, and explanation of any derangements to which they are liable.

"Eleventh. Problems in connection with measurement of coal bunkers, oil tanks, position of weight on safety-valve lever, and so forth.

"Twelfth. Acquaintance with the rules of arithmetic through percentage and proportion, and of mensuration, to enable the solution of such problems as in paragraph eleven. Legible handwriting and knowledge of spelling and grammar.

"Thirteenth. Ability to make a sketch, with figured dimensions, from the machinery, so that in case of a broken part a new one could be made from his sketch.

"SEC. 166. *Chief engineer:*

"First. *Boilers.*—This shall include all the common makes of boilers likely to be found in any vessel on which the applicant would serve, and also a knowledge of how the various parts are put together, the advantages of different kinds of riveting, the methods of bracing, the attachments commonly used, including improved forms, and the use of forced draft, and the changes in boilers consequent thereon.

"Second. *Engines.*—The different kinds in common use, including those used with paddle wheels; description of their different parts and methods of fitting them together.

"Third. *Valves.*—Different kinds in common use and advantages of forms now in use over older ones which have been abandoned. How to set valves. Cut-off, how effected, and how different points of cut-off change dimensions of valve. Description of modern valve gears with screw and paddle engines, explanation of working, and how variable cut-off is secured with them. Derangements common to valves and valve gear.

"Fourth. *Journals.*—How fitted in different places, provision for lubrication, for preventing heating, and for taking up wear. This is to include shaft and connecting-rod journals and thrust bearings.

"Fifth. *Condensers.*—Object of, explanation of forms in com-

mon use. Methods of packing tubes, preventing crawling, and for good distribution of the steam.

"Sixth. *Pumps.*—Air, circulating, feed and auxiliary pumps; description of the varieties in common use. Description of their connections, as of air and circulating pumps to the condenser. Vacuum, how produced; value of, and how affected by derangement of pumps or peculiarities of working of engine.

"Seventh. *Propelling instruments, including screw and paddle wheel.*—Description of the forms in common use and explanation of the advantages of forms now in use over older ones. Description of methods of securing propelling instruments to shafts and of bearings for same.

"Eighth. *Electric Machinery.*—Practical description of dynamo-electric machines, as fitted on board ship, and of the parts requiring adjustment. Accidents likely to occur to dynamos, and what to do to remedy them. Practical points on the wiring of ships, and points to be looked after to insure good working. Electric lamps and connection to mains.

"Ninth. *Refrigerating and Hydraulic Machinery.*—Description of the forms commonly fitted on board ship. Description of process of working and statement of points to be looked after to insure good working.

"Tenth. *Care of Machinery.*—This will include questions in regard to precautions to be observed in raising steam so as to prevent injury to engines and boilers; precautions to be observed to prevent derangements while in operation; procedure on reaching port and laying up for a few days, and procedure when engines and boilers are to be laid up for a long period, say of several months or more.

"Eleventh. Accidents liable to occur, even with care, and how to remedy them.

"Twelfth. Accidents liable to occur due to carelessness or neglect, and what should be done if they do occur.

"Thirteenth. Accidents that have occurred in applicant's own experience or of which he knows, and what was done to remedy them.

"Fourteenth. List of machine and hand tools usually carried

on board ship, and general idea of work that can be done on board in any case of necessity.

"Fifteenth. Economy in the use of stores. Tell how engines should be run, firing of furnaces conducted, and lubrication looked after and regulated so as to secure the best economy. Effect of change of pitch of propeller on economy. Also of variation in ratio of heating to grate surface.

"Sixteenth. He must be acquainted with the principles of expansion and the modern theory of heat, and be able to solve, with the assistance of his own books or without books, according as the examination papers may be set, questions in economy and duty in connection with engines and boilers.

"Seventeenth. He must understand how to apply the indicator and to draw the proper conclusion from diagrams, and to construct the approximate diagrams for any given data.

"Eighteenth. He must be able to produce, without a copy, a fair working drawing of any part of the machinery, with figured dimensions fit to work from.

"Nineteenth. Strength of materials: Calculations for thickness of boiler shells, size of bolts to stand a given strain, and so forth.

"Twentieth. Inspection of coal, oil, and so forth: Points to be desired and those to be avoided.

"Twenty-first. He must be able to explain the formation of scale and the precipitation of salt, and the precautionary means adopted in respect thereto, with jet condenser and with surface condenser.

"Twenty-second. He must understand the general principles involved in the construction of the vacuum and steam gauges, of the barometer, thermometer and salinometer.

"Twenty-third. He must be familiar with the general results obtained from past experience in relation to corrosion, pitting, and galvanic action in boilers, and the use of zinc and of soda in boilers.

"Twenty-fourth. He must possess an intelligent knowledge of the properties of the lubricants, boiler cements and india rubber in general use in steamers.

"Twenty-fifth. He must understand the cause of spontaneous combustion and the formation of explosive gases in coal holds, and the precautionary measures proper to prevent accidents from these causes.

"SEC. 167. Special examination for the two highest grades of chief engineer: First. Theory of the steam engine. Explanation of the advantages of multiple expansion engines, steam jacketing, high speeds, and so forth.

"Second. Theory of boiler design and construction. Effect of changes in ratios of heating and grate surface, area through tubes and chimney. Production of draft, natural and forced. Influence of proportions on economy of steam production. Features of design requiring special care to insure good circulation, prevent foaming, and so forth.

"Third. Theory of boiler incrustation and corrosion and explanation of means taken to prevent and remedy effects of same.

"Fourth. Theory of condensers and connected pumps. Elements necessary to economy and efficiency.

"Fifth. Design of machinery and boilers of a given power.

"Sixth. Strength of materials. Ability to calculate necessary size of any part of the machinery and boilers.

"Seventh. Theory of friction as presented in marine machinery: Antifriction metals. Lubrication and lubricants, including inspection and tests of latter.

"Eighth. Valves and valve gears. Thorough knowledge of the various kinds, the theory of their action, advantages and disadvantages, and what considerations govern the choice of a particular valve gear for special use.

"Ninth. Theory of electric-light installations on board ship, including details of dynamos, wiring, safety fuses, and so forth; care of dynamos; precautions to be followed in wiring, and so forth.

"Tenth. Theory of refrigerating machinery and precautions to be looked after in its installation.

"Eleventh. Theory of hydraulic machinery, including pumps, hoists, steering gear, and so forth; details of installation, and so forth.

"Twelfth. Building machinery and erection of same on shipboard. The applicant must be able to tell the whole process of building any part of the machinery and boilers, and give the details of its alignment and erection on board ship.

"Thirteenth. Questions on supposititious breakdowns will be given and the applicant asked for his explanation of the best method of repair, if a repair is practicable, or what should be done to get the vessel into port if the break cannot be repaired.

"Fourteenth. Questions will be given to test the ability of applicant to estimate the time and cost for repairs to be made in port, full details of the parts to be repaired being given."

XI.

ON BALANCING MARINE ENGINES AND THE VIBRATION OF VESSELS.

By Mr. A. F. Yarrow.

A paper read before the Institution of Naval Architects (England) at the spring session of 1892.

All who are acquainted with the working of steamers provided with large power and of high speed, such as torpedo boats, torpedo boat catchers, and very fast passenger steamers, will be familiar with the fact that they are subject to considerable vibration under some conditions, especially since the adoption of steel for shipbuilding and high piston speed. To overcome it is daily becoming a matter of increasing importance, as higher and higher speeds are being continually demanded. It is to a study of the laws which govern this vibration, and to the possibility of avoiding it, that I invite your attention this evening.

I will first describe some experiments which we have carried out during the last few years, with a view to throw light upon

the subject. At the outset we felt the want of some means of accurately indicating and recording the extent and character of vibrations, and therefore devised an instrument for the purpose. This instrument I have here this evening for your inspection. It has been in use for the last six years, and is, I believe, trustworthy. It consists, as will be seen, of a heavily-weighted drum, suspended by elastic connections. This drum is provided with suitable clock-work to cause it to revolve, and is regulated to make one revolution per minute. Attached to an upright fixed to the stand of the machine is a pencil which presses lightly against the drum, round which a sheet of paper is wrapped, in the same manner as in an ordinary indicator. It will be readily understood that if the base of this instrument be placed upon a platform or the deck of a vessel subject to vertical vibration, this movement will be transmitted to the whole apparatus, excepting that portion which is suspended by the elastic connection, and this, being heavily weighted, will not follow the vibratory motion of the stand. Now, if we place our instrument on the stern or any part of a steamer which is vibrating, and start the drum revolving, the pencil, being pressed against the paper, makes a line, indicating the relative vertical positions of the pencil and the paper, or, in other words, makes a diagram which records the character and extent of the movement of that part of the ship upon which the instrument stands. This instrument we call a vibrometer, and it has mainly been devised by my friend Mr. Nesbitt.

I believe the cause of vibration in screw vessels, when running in smooth water with their propellers well immersed, to be mainly due to the forces produced by the unbalanced moving parts of the machinery, such as the pistons, piston rods, valves, gear, &c., excepting when it is the result of bad workmanship or bad state of repair. For example, as clearly pointed out by Mr. Barnaby in his treatise on "Marine Propellers," vibration may be set up by a screw, the center of gravity of which is out of the center line of the shaft, or it may be due to want of uniformity in the position, area or shape of the blades. These causes being avoidable by proper care, I do not propose to deal with them. I

would, however, take this opportunity to observe that sufficient attention is not always paid to these points.

From our experiments we have overwhelming proof that the vibration in a torpedo boat is precisely the same in extent and character when the screw is on, and the vessel driven by it through the water, as it is when the boat is stationary and the engines simply revolving without doing work, the propeller being removed. To prove that this statement is correct, I would beg your reference to Fig. 2, upon which are shown enlarged vibrometer diagrams, which have been obtained from torpedo boats when running and when stationary. These diagrams represent a fair average of over a hundred results. It will be seen that diagrams A and A^1 are practically alike; also diagrams B and B^1, and diagrams C and C^1, A, B and C having been obtained when the boat was under weigh with propeller on, and A^1, B^1 and C^1 when the vessel was stationary, being without propeller. The engines were making exactly the same number of revolutions in each corresponding pair of diagrams. Not only do these diagrams prove that the screw had nothing to do with the vibration, and that it was owing to the working of the machinery, but it will be seen how greatly our investigaton is facilitated by these facts, because experiments can be carried out with a boat at rest, and we know that the same results as regards vibration will be found under ordinary working conditions.

It is a well-known fact that engines will impart their vibration to a boat at certain speeds much more readily than at other speeds, and it often happens that at full speed a boat may be practically steady, while at a slower speed the vibration is excessive. This is dependent upon the extent to which the movements of the reciprocating parts of the engine correspond with the period of vibration of the hull, which may be considered in this investigation as an elastic body. This is illustrated by the well-known fact that when soldiers are crossing a suspension bridge it is often found necessary to avoid their marching in step. Some years since we had a boat in which severe vibration occurred at 200, 400, 600 and 800 revolutions per minute. But there was none at the intermediate speeds of 300, 500 and

700. The diagrams on Fig. 3 show very clearly how the vibration varies at different speeds, and the variation that takes place in the extent of the vibration when passing from one speed to another.

In a vessel such as a fast Atlantic liner, which is intended to run continuously at a nearly uniform speed—unless special means be taken to balance the machinery—it is of the utmost importance to carefully avoid the number of revolutions of the engines per minute keeping the time with, or, in other words, synchronizing with the normal vibration of the hull. This can not be carried out in the case of war ships and others which are intended to run at varying speeds; for if the speed of the engines be proportioned so as not to set up vibration at full speed, they will probably do so at intermediate or cruising speeds, and if they set up no vibration at cruising speeds they will probably vibrate at full speed. I believe it would be by no means a difficult matter to determine in the original design, with fair accuracy, what speed of engine would be suitable to avoid vibration being set up in any given design of hull. We frequently hear of propellers being changed in order to reduce vibration, and in many cases the change is made with advantage; but it often happens that the improvement is not directly due to the altered shape of the propeller, but indirectly to the change causing an alteration in the number of revolutions of the engine, and thereby preventing them synchronizing with the natural vibration of the ship. We hear of hulls being strengthened or built stronger than would otherwise be necessary, with a view to reduce vibration. Doubtless this is done with more or less success, due, possibly, not so much to the greater strength of hull but rather to the period of vibration being modified by this stiffening, so as to avoid its harmonizing with the movements of the machinery. Building vessels of greater strength than would otherwise be necessary, with the object of avoiding vibration, cannot be considered a scientific method of dealing with the difficulty, if it can be proved that vibration can be avoided by other means and without extra weight, because extra weight of material added to the ship tends to handicap its speed. The true cause of vibration being due to the machinery, I think it will be

admitted that the correct mode of dealing with it is to so design the engines that they may be steady within themselves and free from any tendency to cause the hull to vibrate. As a further proof that the vibration is due to the machinery, I may mention that two years ago I made a passage to the United States in one of the very fast twin-screw steamers. I selected a berth in the central portion of the vessel, thinking it a good position for comfort, but the vibration was found to be so excessive that, after five days, it was scarcely bearable to those passengers whose berths, like my own, were situated at the points of greatest vibration. The vibration was found to vary periodically. When the two low-pressure pistons were descending at the same time it was excessive, but when one low-pressure piston was ascending and the other descending at the same time it was entirely neutralized. So distinct was the vibration in my cabin that it was quite easy to count the number of revolutions of the port and starboard engines, and we rigged up a temporary vibrometer on our cabin side, which gave us diagrams, indicating clearly the movements we were subject to. I believe all who have studied the subject of vibration in steamers will agree with me that many vessels which vibrate considerably are in consequence credited with weakness, while in reality they are of ample strength, the fault resting entirely with the engines and not with the hull. Not only is this vibration a source of discomfort to passengers, but it clearly adds considerably to the wear and tear of the vessel.

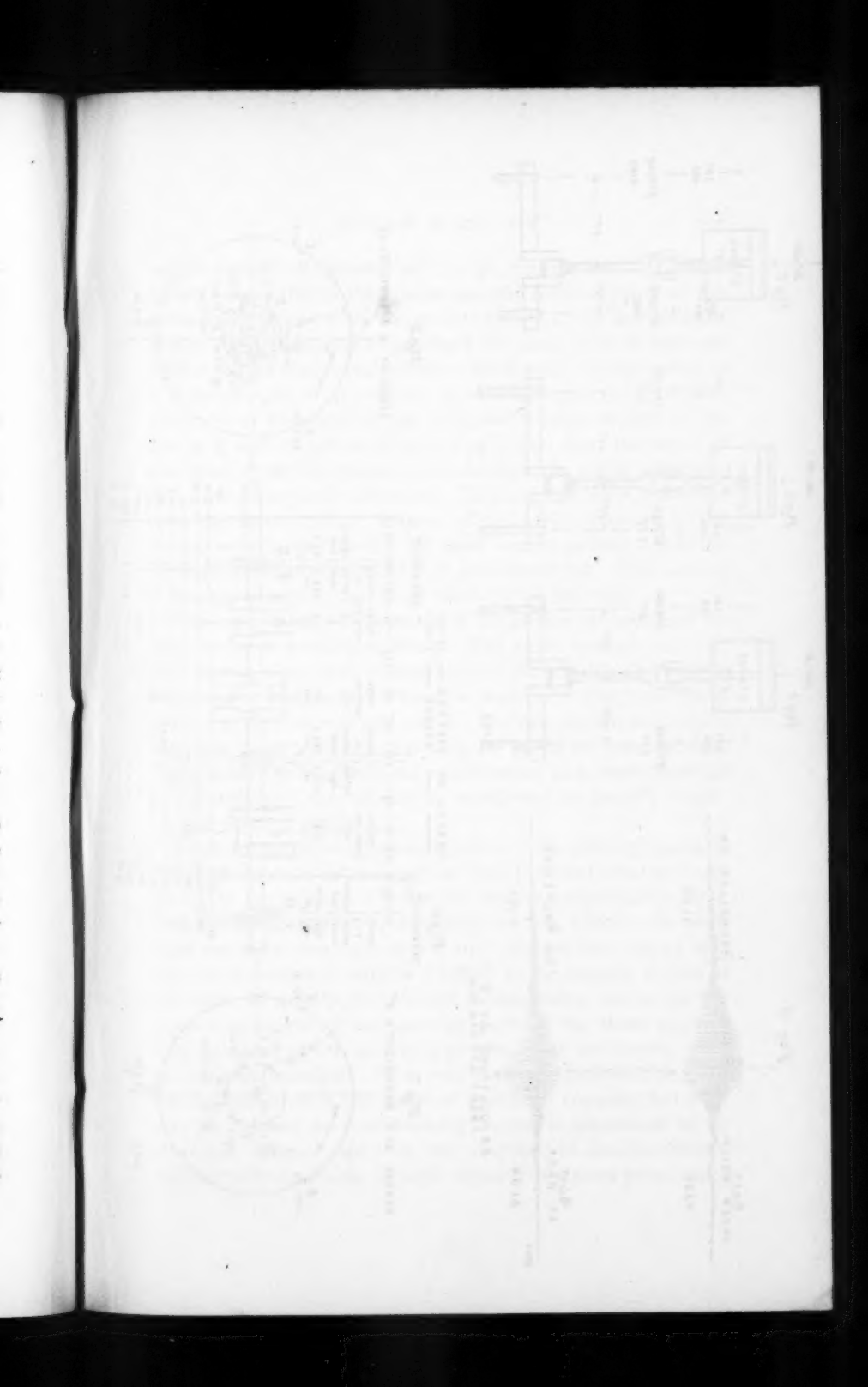
Let us consider exactly why an engine produces vibration. In an ordinary inverted engine the steam presses on the cylinder cover and on the piston, and from the piston the stress is transmitted to the bed plate. Now, during the first half of the downstroke the upward pressure on the cylinder cover is greater than the downward pressure on the bed plate to the extent of what is needed to set the reciprocating parts in motion, and this excess of upward over downward pressure lifts the engine bed and that portion of the hull to which it is attached. By a like train of reasoning it can be shown that during the latter half of the downstroke and the first half of the upstroke the tendency is

to lower the engine bed; also that during the second half of the upstroke the tendency is to raise the engine bed. To sum this up in a few words, during the upper half of the revolution the engine tends to lift the vessel, and during the lower half to depress it. The main principle which governs the whole matter may be thus summed up: As no internal force can move the center of gravity of a body, it follows that any momentum generated by steam pressure in the moving parts, such as the piston, &c., must be attended by an exactly equal momentum in the rest of the ship in the opposite direction.

We will now pass on to consider how to design engines so that they may be perfectly free from vibration. For this purpose please refer to Fig. 4, representing a single-cylinder inverted engine, which, for the sake of simplicity, we will assume has no valve gear. The revolving parts, such as the crank, crank pin and a portion of the connecting rod, can be balanced by means of rotary weights in the usual way, and we then have only the vertical unbalanced parts, such as the piston, piston rod, &c., left to deal with. Now, if we have two eccentrics set opposite to the crank, at equal distances from it and of equal stroke to it, and these impart an up-and-down motion to weights, which we will call "bob weights," each of which is half as heavy as the parts to be balanced, that piece of mechanism will revolve free from vibration, excepting that which is due to the angle of the connecting rods. If we wish to place these weights at unequal distances from the crank (see Fig. 5) they must be proportioned to vary in weight inversely as their distances from the crank—that is, if one weight be twice as far from the center of the crank as the other, it will have to be half the weight of the other, the sum of the weights in this case being the same irrespective of their position. If we desire to reduce the stroke of these weights so as to obtain a convenient length of stroke (see Fig. 6) we shall then have to increase their weight inversely as the stroke—that is, if we quarter the stroke, the weight will have to be quadrupled, and so forth. It will thus be seen to be a simple matter to proportion the bob weights, their stroke and their position, to suit what may best work in with any design of engine.

To sum up in a few words what must be done to avoid the effect of the momentum generated by the working parts being felt by the hull, an equal momentum in an opposite direction should be produced. If, instead of using bob weights, rotary weights of equal amount had been employed, having their centers of gravity in the same position as the centers of the eccentrics, which give motion to the bob weights, the engine would still be balanced vertically, but would be unbalanced horizontally.

I would now direct your attention to Fig. 8, showing the calculation as applied to triple-expansion vertical engines. The most suitable positions are first determined for fixing the two eccentrics which give motion to the bob weights, in this case the one lettered *X* being at the forward end of the engines, and the other lettered *Y* being between the low-pressure crank and its valve eccentrics. Each unbalanced moving part in the engine is then dealt with separately, as before described, and the position and amount of the weights necessary to balance it ascertained, the stroke of the balance weights being taken, for the purpose of calculation, as equal to the stroke of the part they balance in each case. For instance, take the middle-pressure piston, piston-rod, &c., lettered *B*, the unbalanced reciprocating parts of which weigh 162 lbs., the balance required at *X* is found to be 81.8 lbs., and at *Y* 80.2 lbs., the stroke of each being 16 inches. Taking another instance, for example the high pressure valve and its go-ahead gear, lettered *E*, weighing 264.5 lbs., the balance at *X* is found to be 228.25 lbs., and at *Y* 36.25 lbs., the stroke of each being 5 inches. After dealing in a similar manner with all reciprocating parts, if we were to construct two uniform discs with each of the weights thus found pinned on in its proper relative position, and place them respectively at *X* and *Y*, the engine would be balanced vertically. All the weights at *X* might be replaced by one large weight equal to the sum of them, and having the same position of center of gravity; in a like manner the weights of *Y* may be dealt with. These are shown by the large black spots on the diagram. These, again, might be substituted by larger or smaller weights as convenient, situated nearer or further from the center of the shaft, the amount of the



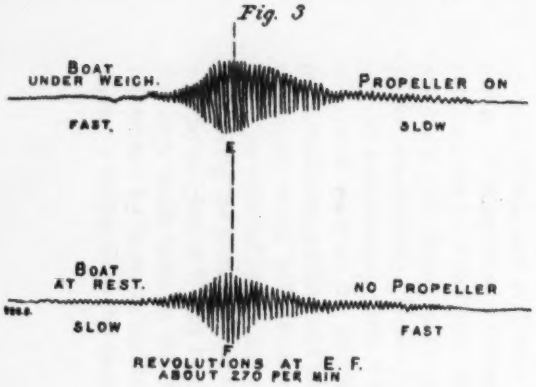


Fig. 3
BOAT UNDER WEIGH.
PROPELLER ON
FAST.
SLOW
E
BOAT AT REST.
NO PROPELLER
SLOW
FAST
F
REVOLUTIONS AT E. F. ABOUT 270 PER MIN

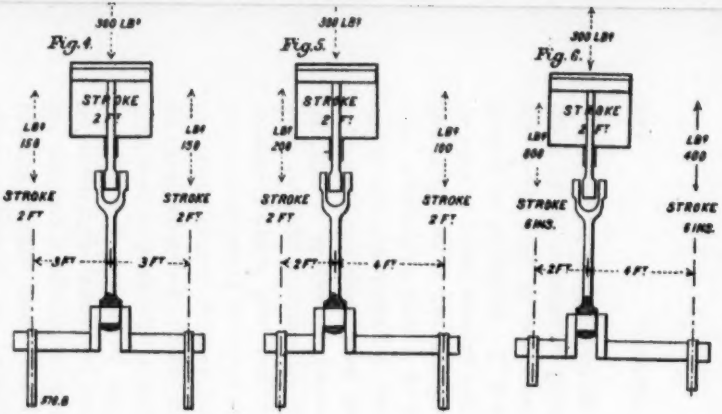


Fig.4.
300 LBS
STROKE 2 FT
STROKE 2FT
3FT
3FT
Fig.5.
300 LBS
STROKE 2 FT
STROKE 2FT
2FT
4FT
Fig.6.
300 LBS
STROKE 2 FT
STROKE 6 INS.
STROKE 6 INS.
2FT
4FT

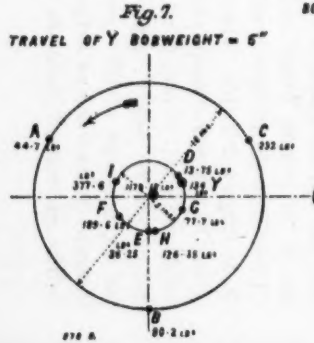


Fig.7.
TRAVEL OF Y BOBWEIGHT = 6"

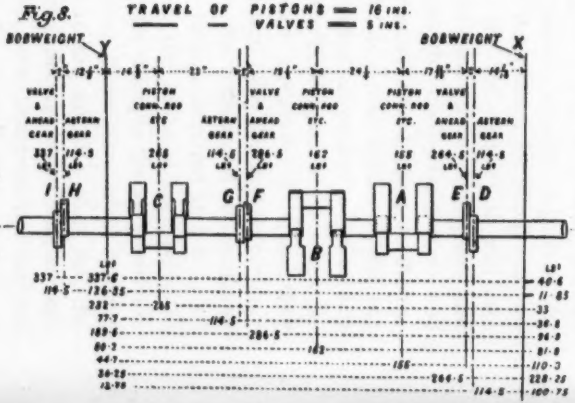


Fig.8.
TRAVEL OF PISTONS — 16 INS.
VALVES — 5 INS.
BOBWEIGHT Y
BOBWEIGHT X

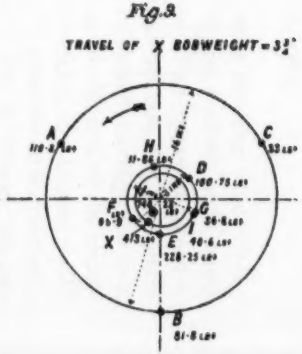


Fig.9.
TRAVEL OF X BOBWEIGHT = 3 1/4"

weight being in the inverse ratio to the distance from the center. It will be seen that in the present case the total weight of all the balances equalled 740.25 lbs. at *X* and 1,178.15 lbs. at *Y*, and the distance of their center of gravity from center of shaft was 1.04 inches and .28 inches respectively; these would be equivalent to a rotary weight of 413 lbs. at *X*, with its center of gravity $1\frac{7}{8}$ inches from the center of the shaft, and a rotary weight of 134 lbs. at *Y*, with its center of gravity $2\frac{1}{2}$ inches from the center of the shaft, these two weights would balance the engine vertically, but would set up side vibration. To avoid the latter and retain only the vertical effect, the use of bob weights equal to the rotary weights, and having the same vertical motion and in the same relative position on the shaft, are substituted. This method was adopted in the engines we shall refer to later on.

The correctness of this mode of calculation is confirmed by experience in practical working. The exact amount, position, and stroke of the bob weights can be accurately calculated in the original design, and if they be made accordingly no vibrations will take place at any speed. The calculations are simple, but care must be taken that they are based on accurate data. To estimate the weights of the reciprocating parts from drawings is not sufficient; they should be ascertained by actually weighing the finished articles.

Triple-expansion engines with three cranks, although partially balanced when at rest, are very far from balanced when at work, owing to the distance between the various reciprocating parts, which consequently set up a rocking motion, which is the principal one to be overcome, and in such engines this rocking motion we have to deal with in addition to the vertical motion of the center of gravity, this vertical motion being due to the difference in weight of the working parts of the three engines. The positions of the bob weights should be so chosen as to minimize their weight. What weight may be necessary to avoid vertical vibration of the center of gravity is constant, but what may be required to avoid rocking motion is diminished by an increased distance apart of the weights. In double-cylinder engines with the cranks at right angles it is a more pronounced

galloping motion, *i. e.*, a motion of a complex kind, being a compound of vertical motions of their center of gravity and a rocking motion. In a single-cylinder engine the vibration of the engine is practically up and down; but with whatever type of motion we have to deal, the same principle of balancing holds good. All forces causing vertical vibration can be neutralized by the use of bob weights, arranged to set up equal forces acting in an opposite direction. Some years ago we thought the vibration in triple-expansion engines was due to the difference in weight of the pistons, and with a view to balance them, and, as we supposed, avoid vibration, we made each piston of the same weight in a first-class torpedo boat; thus we prevented any vertical movements of the center of gravity of the engines; yet we found no improvement. This clearly indicates that the rocking vibrations are of more importance than the vertical vibrations in triple-expansion engines.

There is one feature about the vibration of vessels which deserves attention, viz., that it varies in intensity at different points in the length of the hull; there are places where it is excessive, and places, termed nodes, where it does not exist. I will now refer you to Fig. 10, representing some engines indicating about 1,100 horse-power for a first-class torpedo boat, 130 feet in length by 13 feet 6 inches beam, having a speed of from 22 knots to 23 knots, carrying a load of 20 tons. There is nothing special about the engines excepting the two eccentrics fixed on the shaft at each end, working vertical bob weights. To the cranks were fitted weights sufficient to balance them, the crank pins, and partially the connecting rods. How far each connecting rod was balanced by rotary weights was determined by its weight and the lateral movement of its center of gravity; what remained unbalanced was balanced by the bob weights worked by the eccentrics, their stroke and weight being calculated as already explained when describing Fig. 6. Experiments were made with this boat in the Thames, and also in the West India dock. We tried her under three conditions: (1) without any balance weights whatever, as engines are usually constructed; (2) with balance weights on the cranks only; and (3) with bal-

ance weights on cranks and bob weights. The amount of vertical vibration at the stern, as obtained in the river, is given on Fig. 11, together with enlarged vibrometer diagrams, from which it will be seen that the results corresponding to the three conditions show a vibration of $\frac{27}{64}$ inch, as usually made, $\frac{20}{64}$ inch with balance weights on cranks, and $\frac{7}{64}$ inch with balances on cranks and bob weights. I have not the slightest doubt, from more recent experience, that this small vibration that remained could still further be reduced, and in fact practically avoided altogether, by taking greater care in accurately ascertaining the weight of all moving parts. The foregoing trials were all made at 248 revolutions per minute, which corresponded in this boat to the speed producing maximum vibration; that is to say, when the movement of the engine synchronized to the greatest extent with that of the boat. I believe that the vibration of the largest Atlantic liner can in this way be practically overcome by the expenditure of a few hundred pounds, if carried out in the original design. Bob weights proportioned and arranged as already described may be reduced in amount if wished, being substituted by a rotary balance weight equal to such reduction; this, however, must not be carried out to an extent to produce sensible side vibration.

Thinking it would be of interest to the meeting, and in confirmation of the statements put before you, I propose to throw on this screen a series of instantaneous photographs, taken while our experiments were being carried on. In all cases the revolutions were 248 per minute, and it is the ripples on the water produced by the vibration of the boat to which I would direct your attention. Fig. 12 shows the effect at the bow without any balance weights as usual in producing ripples on the water due to the vibration of the hull. Fig. 13 shows the effect with bob weights and balance weights on cranks as described. Fig. 14 shows the effects at the stern in producing ripples with the engines constructed as usually made at 248 revolutions, and Fig. 15 represents the effect under precisely the same conditions, excepting that the balance weights are in use. Fig. 16 gives a broadside view without balance weights, from which not only can the disturbance of the water in the immediate vicinity of the

boat be seen, due to its vibration, but the points where the vibration is the greatest, and the position of the nodes where there is no vibration. Fig. 17 shows the boat under exactly the same conditions with balance and bob weights in which the disturbance of the water is so small as not to be noticeable in the photograph. To show how easily a boat of this description may be set vibrating when the number of impulses correspond to its natural period of vibration, I beg reference to Fig. 18, showing the vibration produced by simply one man springing on the stern.

To further illustrate the system and prove its correctness, I have here a model corresponding to a triple-expansion engine; the weights of the piston have been similarly proportioned to one another as in our torpedo boat engines. It will be seen that the shaft is made to revolve by flexible wire so as to avoid the result being vitiated by the mode adopted for causing it to revolve. This model engine is suspended by springs in order to be quite free to move vertically. You will notice when we set it going that unmistakable vibration is at once set up. The rotary weights, such as crank, crank pin and lower ends of connecting rods, are all carefully balanced by balanced discs, and consequently, this vibration is due entirely to the moving parts. We will now connect the bob weights on each side, the amount, stroke and position of which have been arrived at by similar calculation to that already described. The effect of these bob weights in completely avoiding the vibration will be clearly seen.

In conclusion, I would desire to thank those members of my staff who have been occupied with me in carrying out these experiments—Mr. Crohn, Mr. Nesbitt and Mr. Marriner—for the able way in which they have assisted me in the investigation I have had the honor of laying before you this evening, which, I hope, you will consider of interest.

[Only such of the diagrams illustrating Mr. Yarrow's paper are here given as are absolutely needed to explain the test. The photographs mentioned are very interesting, but the cost of their reproduction forbids their presentation. They are given in "Engineering" for April 15, and the "Engineer" (London) for April 8. The paper and diagrams given have been taken from these journals.—*Editor.*]

FOX'S CORRUGATED FURNACES.

The corrugated furnace, invented by Mr. Samson Fox of Leeds, England, is probably by far the best known of the stronger forms of boiler furnaces, and certainly many more have been used than of any other make.

The formulæ governing the strength of this furnace, in use until recently, were based on experiments made in 1882 and witnessed by experts from the British Admiralty, the Board of Trade and Lloyd's Register. In explanation of the way in which the test was made, the report of Mr. William Parker, so long Chief Engineer Surveyor to Lloyd's, is here given:

"LLOYD'S REGISTER OF
"BRITISH AND FOREIGN SHIPPING,
"*November 28, 1882.*

"In accordance with the instructions contained in your letter of the 23d inst., I proceeded to Leeds to attend a test to destruction of a rolled corrugated flue or furnace, for the purpose of obtaining some further information on the strength of such structures.

"Several previous experiments on the strength have been made to ascertain the strength of these furnaces as compared with plain ones of the same diameter and thickness, and, although the corrugated flues then experimented upon were not truly round, they showed such a decided excess of strength over plain furnaces that it was considered that a pressure of at least 25 per cent. over that allowed for plain flues could by safely permitted for them. The method of manufacture until recently adopted with these furnaces was to form a plain cylindrical surface and then produce the corrugations by hammering it between large swages. By this process it was exceedingly difficult to insure the furnaces being truly round when finished, and this materially weakened the furnaces, as any deviation from the circular form necessarily causes a loss of strength. In order to obviate this result, and

also to provide adequately for the increased demand for corrugated furnaces, the Leeds Forge Company have recently laid down a large rolling mill for the manufacture of the flues. By this method they are made perfectly true, and must, therefore, be stronger than those made by the original process. The experiment conducted on Friday last was intended to show the extent of this superiority.

"The experimental furnace was 6 feet 9 inches long, 3 feet 1⅞ inches outside diameter, had 13 corrugations 1½ inches deep, and pitched 6 inches apart from center to center of each corrugation. The material composing the flue was mild steel, which was shown by the testing of a piece cut from the plate to have a tenacity of 22.7 tons per square inch, with an elongation of 35 per cent. in a length of 10 inches. The furnace was enclosed in a strong wrought iron cylinder specially made for the purpose, the annular space between the furnace and cylinder was filled with water, and by means of a hydraulic pump the requisite pressure was applied. Two of Messrs. Dewrance's large pressure gauges were attached to the cylinder to indicate the pressure being exerted upon the furnace.

"Before any pressure was applied the furnace was carefully gauged for roundness, and it was found to be perfectly true along its whole length.

"The pressure was then applied, and at each increment of 100 lbs. per square inch the furnace was carefully gauged, both vertically and horizontally, at the central corrugation, and the third one from each end, and also longitudinally, so that the elongation under various pressures, the limit of elasticity of the material, and the ultimate strength to resist the collapse, should be ascertained. As will be seen from the attached table of results, up to a pressure of 500 lbs. per square inch no alteration in the cylindrical form of the furnace was perceptible, but it had slightly elongated even from the first application of 100 lbs. pressure; at 800 lbs. it had sprung or altered its circular form to the extent of $\frac{1}{32}$ inch, while it had gone on steadily elongating to fully $\frac{1}{6}$ inch; but on the pressure being released it entirely recovered its original shape; at 850 lbs. pressure its alteration was slightly

increased, and on relieving the pressure permanent set could be distinctly measured both cylindrically and longitudinally, and at a pressure of 900 lbs. per square inch it slowly collapsed, altering its form more readily than could be followed up by the pump.

"After this twelve holes were drilled at various parts of the furnace to ascertain the actual thickness of the plate, and the various places showed thicknesses varying from .51 to .53 of an inch.

"This experiment shows that the ultimate crushing strength of the furnace could be expressed by the formula:

$$\frac{60{,}000 \times t}{d}$$

where t is the thickness of the plate and d the mean diameter of furnace.

"As a result of this and previous experiments, I would respectfully submit for the consideration of the Committee that for the future the corrugated furnaces ($1\frac{1}{2}$ inches deep) should be approved of for a working pressure found by the following formula:

$$\text{Working pressure} = \frac{1{,}000 \times (T - 2)}{D}$$

where T is the thickness of the plate in sixteenths of an inch, and D the greatest diameter of the furnace in inches.

"If this rule is adopted, new furnaces of $\frac{9}{16}$, $\frac{8}{16}$, $\frac{7}{16}$, and $\frac{6}{16}$ of an inch in thickness will possess margins of safety of 5, 5.17, 5.45, and 5.62 respectively, while the same furnaces, when their thickness is reduced by corrosion by $\frac{1}{8}$ inch, will in each case possess a margin of strength of 3.9.

"The introduction of the term $(T - 2)$ in the numerator practically provides for the fact that an equal amount of corrosion weakens a structure composed of thick plates to a less extent than it does one made of thin plates. This is already provided for in the Society's rules on the shell and combustion chamber plating of boilers, and should apply also to furnaces.

"I may state that at this experiment I was met by Mr. A. C. Kirk, of the firm of R. Napier & Sons, and by representatives from the Admiralty and from the Board of Trade, who were all

satisfied as to the value of this experiment in arriving at a satisfactory formula for corrugated flues.

"I am, sir, your obedient servant,

"WILLIAM PARKER.

"*The Secretary, Lloyd's Register.*"

The formula proposed by Mr. Parker and the one of the Board of Trade,

$$P = \frac{12{,}500 \times t}{D},$$

were in use until some time last year. Meanwhile, other forms of strong furnaces had been put on the market, and one, the Purves or ribbed furnace, was allowed a higher constant by Lloyd's and the Board of Trade. This naturally led to its cutting into the business of the Fox furnace, and doubtless led to the experiments of which data are given below.

These experiments were made at the expense of the Leeds Forge Company, by the well known engineer, Prof. Alex. B. W. Kennedy, in the presence of experts, as in the case reported by Mr. Parker. Prof. Kennedy's report has not been published, but, through the courtesy of Mr. Warren E. Hill, of the Continental Iron Works of Brooklyn, the Society is able to publish the tables and diagrams which are the important matters of the test. As will be seen by examination, the tests were very elaborate and careful, and they demonstrated what Mr. Fox had claimed, that his furnace should be allowed a higher constant.

As a result of the experiments, the formulæ for the Fox furnace have been changed, so that they now are:

Lloyd's Register.—$P = \frac{1{,}234\ (T - 2)}{D}$

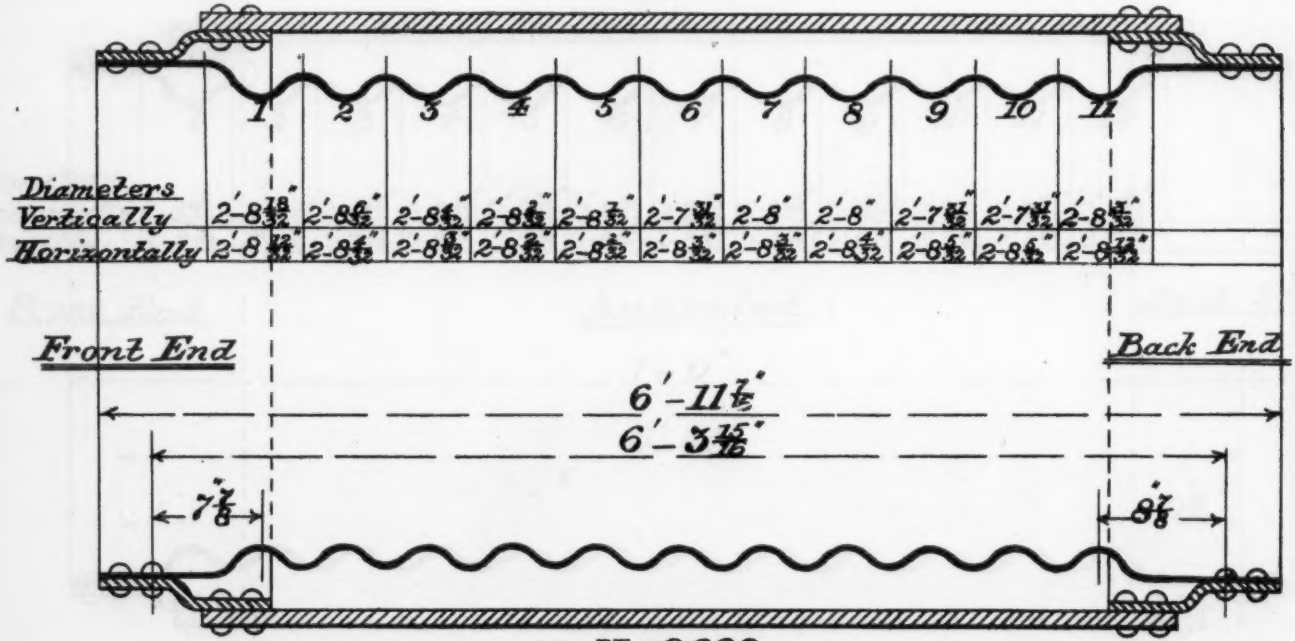
where

P = working pressure in pounds per square inch above atmosphere;

T = thickness in sixteenths of an inch, expressed as an integer;

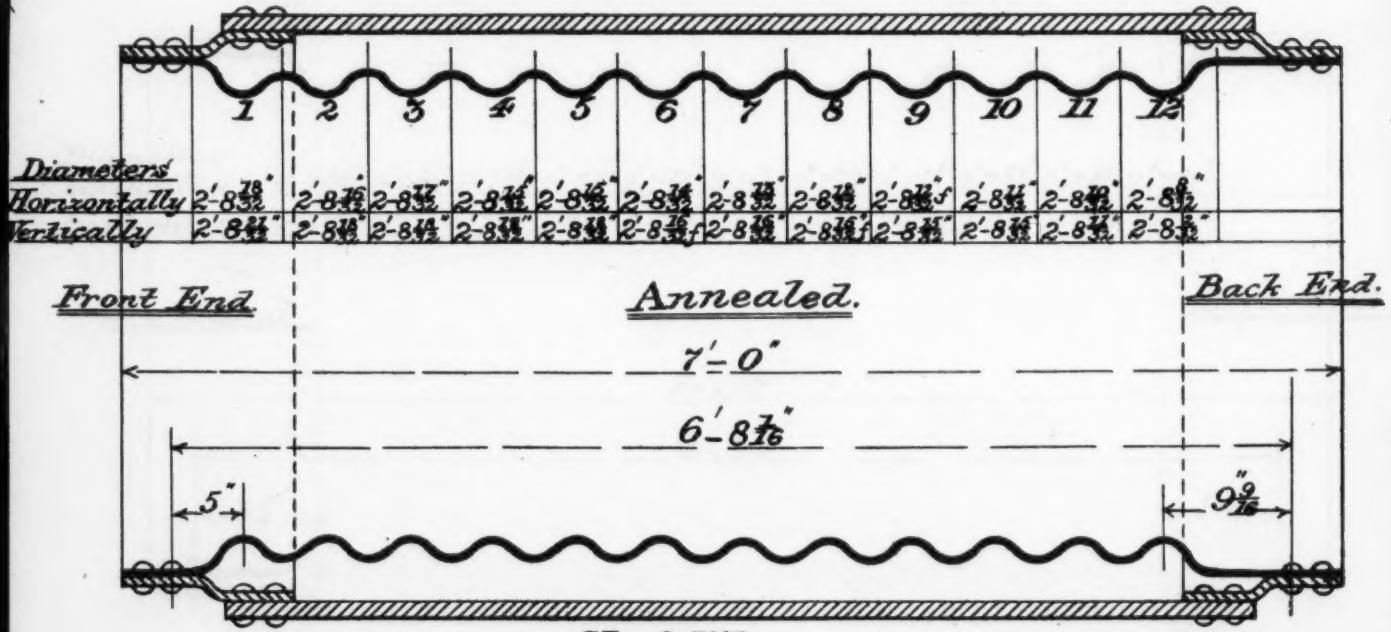
D = greatest external diameter in inches.

Board of Trade.—$P = \frac{14{,}000 \times T}{D}$



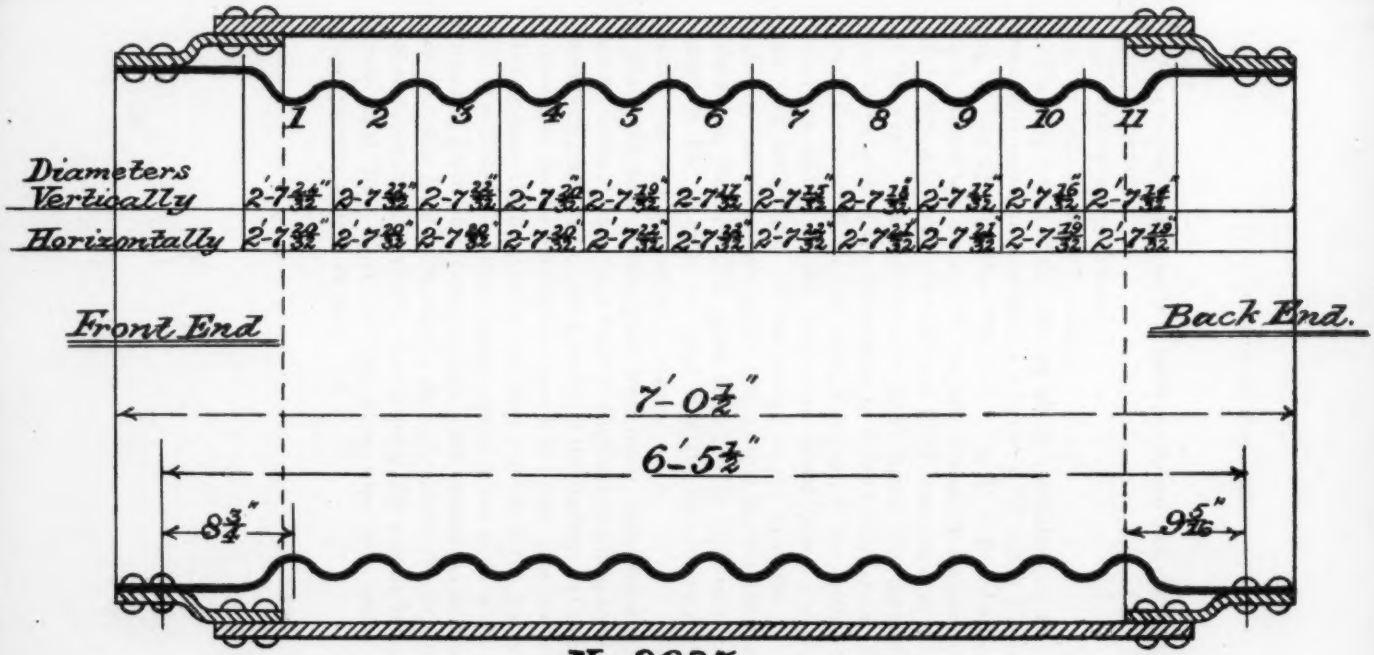
No. 2622.

6/16 inches.



No. 2571.

1/16 inches.



No. 2623.
9/16 inches.

where

P = working pressure in pounds per square inch above atmosphere;

T = thickness in inches;

D = mean diameter in inches.

The only notice of this change which has hitherto been given general circulation consisted in a letter to "London Engineering" of July 24, 1891, from Mr. Fox. The U. S. Board of Supervising Inspectors authorized the new formula (the same as that of the Board of Trade) in a circular which was issued in January of this year. The new formulæ (both forms) also appeared in the later copies of the last edition of Foley's Mechanical Engineer's Reference Book, but most, if not all, of the copies of the American edition of this work were issued before the change had been authorized. It was owing to the fact that so little publicity had been given to the change that the old formula was retained in the Frye Bill, given elsewhere in this number. As stated in the footnote on page 223, the new formula will be inserted in the Bill when it is revised.

Since the tests herein given were made, competitive tests of several furnaces have been made in England, of which some data have been submitted to the Council of the Society. If complete information can be obtained in time, it is hoped that the results of these tests can be given in the next number of the JOURNAL.

The publication of the detailed results of the trials of the Fox furnace is given on account of their great interest, as well as the act that this form of furnace is the only one of the strong furnaces as yet manufactured in this country, the makers being the Continental Iron Works of Brooklyn, who work under Mr. Fox's patents, as well as their own.

CORRUGATED FLUE TUBE.—TESTED AT LEEDS FORGE, NOV. 4 AND 5, 1890.

NOMINAL THICKNESS FIVE-SIXTEENTHS INCH. No. 2,622.

	Measurements taken at A No. 1.		Measurements taken at B No. 6.		Measurements taken at C No. 11.	
	Vertical.	Horizontal	Vertical.	Horizontal.	Vertical.	Horizontal.
Dimensions taken before test.	2′ 8 1/16″	2′ 8 1/16″	2′ 7 31/32″	2′ 8 1/32″	2′ 8 3/32″	2′ 8 1/32″
Pressure in pounds per square inch.	Movement.		Movement.		Movement.	
100	Nil.	Nil.	Nil.	Nil.	line in	line out
200	line in	"	"	"	"	"
300	1/16 in	"	trace of m in	"	1/32 f in	"
400	1/32 b in	"	"	"	"	"
500	3/64 f in	"	1/32 in	"	1/32 b in	1/32 out
550	"	"	"	"	"	"
600	1/16 in	"	"	"	1/16 in	"
800	1/8 in	1/64 out	1/16 in	"	1/16 in	1/16 b out
830	Flat surface at back end collapsed.					
850	Collapse of flat at back end continued.					
Permanent set after pressure released.	Nil.	1/16 out	trace in	...	1/32 in	...

NOTE.—Measurements to determine the linear extension showed that there was none.

MECHANICAL TESTS OF MATERIAL.

TENSILE TESTS OF SIX SPECIMENS CUT FROM THE PLATE FROM WHICH THE ABOVE NUMBERED FLUE TUBE WAS MADE.

Test No.	Marks on piece	Dimensions. Broad.	Thick.	Area.	Limit of elasticity. Pounds per sq. inch.	Tons per sq. inch.	Breaking load. Pounds per sq. inch.	Tons per sq. inch.	Ratio of limit to break.	Extension on 10″, per cent.	Reduction of area, per cent.	Extension on 10″ at 40,000 per sq. inch.	50,000 per sq. inch.	Remarks.
Not annealed.														
17,800 D	2,622 P. S.	1.492	.310	.463	55,790	24.91	64,370	28.74	.867	18.1	42.8	.01	.03	Silky, somewhat bad reed.
17,801 D	A 419	1.492	.320	.477	53,900	24.07	66,330	29.60	.813	16.5	45.8	.03	.05	Silky, very slightly laminated.
17,802 D	...	1.490	.316	.471	55,510	24.79	64,500	28.80	.861	21.1	49.6	.00	.02	Silky.
Average,	...	...	...	...	...	24.59	...	29.05	...	18.9	46.1	...	...	
Annealed.														
17,803 D	2,622 P. S.	1.495	.330	.493	42,370	18.92	59,400	26.52	.714	19.5	51.0	.03	.38	Silky.
17,804 D	A 419	1.490	.325	.484	38,580	17.22	54,660	24.40	.706	23.6	54.0	.28	.81	Silky, slightly laminated.
17,805 D	...	1.490	.332	.495	39,910	17.82	58,950	26.32	.677	22.0	52.4	.12	.58	Silky, slightly laminated.
...	...	...	...	...	...	17.99	...	25.75	...	21.7	52.5	...	...	

...	...	...	...	...	...	17.99	...	25.75	...	21.7	52.5	...	...

MEASUREMENTS FOR THICKNESS.

Number of test hole.	Front.	Middle.	Back.
1 weld.	.329	.395	.352
2	.345	.364	.328
3	.342	.359	.328
4	.334	.368	.339
5	.336	.366	.329
Mean of unwelded plate.	.339	.364	.331

Mean thickness of front end, .339; middle, .364; back end, .331. Mean thickness of the plate, .344.
Mean thickness of the welded portion of the plate, .358, being .0455 greater than the mean thickness of the unwelded plate. Mean thickness of the unwelded plate was .344, or .0315 greater than the nominal thickness.

COMPRESSIVE TESTS OF SIX SPECIMENS CUT FROM THE PLATE FROM WHICH THE ABOVE NUMBERED FLUE TUBE WAS MADE.

Test No.	Marks on piece.	Dimensions. Broad.	Thick.	Area.	Breaking load. Pounds per sq. inch.	Tons per sq. inch.	Compression on 10" length at 30,000 per sq. inch.	40,000 per sq. inch.	Remarks.
Not annealed.									
17,806 D	2,622 P. S.	1.496	.312	.467	32,970	14.72	.025	...	Gave way by buckling without cracking in all cases.
17,807 D	A 419	1.496	.316	.473	40,790	18.21	.01	.02	
17,808 D	...	1.496	.314	.470	45,920	20.50	.015	.025	
Average,	...	...	...	...	...	17.81	.017	.023	
Annealed.									
17,809 D	2,622 P. S.	1.500	.327	.491	35,210	15.72	.02	...	
17,810 D	A 419	1.500	.327	.491	29,870	13.34	...	...	
17,811 D	...	1.500	.316	.474	30,760	13.74	.01	...	
Average,	...	...	...	...	...	14.27	.015	...	

TENSILE TEST MADE FROM PORTIONS OF THE CORRUGATED FLUE TUBE AFTER THE COLLAPSING TEST HAD BEEN COMPLETED. TEST PIECES CUT FROM VARIOUS POSITIONS IN EACH TUBE.

Test No.	Marks on piece.	Dimensions. B road.	Thick.	Area.	Limit of elasticity. Pounds per sq. inch.	Tons per sq. inch.	Breaking load. Pounds per sq. inch.	Tons per sq. inch.	Ratio of limit to break.	Extension on 10", per cent.	Reduction of area, per cent.	Extension on 10" length at 30,000 per sq. inch.	40,000 per sq. inch.	50,000 per sq. inch.	Remarks.
18,508	2,622 P. S.	1.498	.373	.559	45,100	20.13	62,900	28.08	.717	20.1	50.4	.04	.10	.29	Silky.
18,509	...	1.496	.380	.569	44,560	19.89	63,830	28.50	.698	19.8	45.3	.04	.05	.30	Silky.
18,510	...	1.496	.360	.539	43,170	20.17	64,570	28.80	.700	22.3	49.6	.01	.10	.25	Silky.
Average,	...	...	...	...	44,943	20.06	63,743	28.46	.705	20.7	48.4	.03	.08	.28	

Tests of the material made by Prof. Alex. Kennedy, at his testing works, 19 Little Queen street, Westminster. Copied from report made to T. W. Traill, Esq., the Engineer Surveyor-in-Chief, to the Board of Trade. Copies supplied to the Leed's Forge Co., Limited, Leeds, by Board of Trade, memo. E. S. C., 4571, 90.

CORRUGATED FLUE TUBE.—TESTED AT LEEDS FORGE, FEB. 11 AND 12, 1891.

NOMINAL THICKNESS SEVEN—SIXTEENTHS INCH. No. 2,571.

	Measurements taken at A No. 1.		Measurements taken at B No. 7.		Measurements taken at C No. 12.	
	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.
Dimensions taken before test.	2′ 8$\frac{11}{16}$″	2′ 8$\frac{12}{16}$″	2′ 8$\frac{11}{16}$″	2′ 8$\frac{12}{16}$″	2′ 8$\frac{7}{16}$″	2′ 8$\frac{8}{16}$″
Pressure in pounds per square inch.	Movement.		Movement.		Movement.	
100	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
200	"	"	"	"	"	"
300	"	"	"	"	"	"
500	"	"	"	trace in	"	trace in
700	$\frac{1}{64}$ in	"	"	$\frac{1}{32}$ f in	$\frac{1}{64}$ in	$\frac{1}{64}$ in
800	...	...	...	...	...	...
900	$\frac{1}{32}$ in	$\frac{1}{64}$ in	"	$\frac{1}{16}$ b in	$\frac{11}{64}$ f in	$\frac{3}{32}$ f in
1,000	$\frac{3}{64}$ f in	$\frac{1}{32}$ in	"	$\frac{1}{64}$ in	$\frac{3}{32}$ in	$\frac{1}{4}$ f in
Pressure released to 0	Nil.	Nil.	"	Nil.	$\frac{3}{32}$ in	$\frac{3}{32}$ in
1,090	Collapsed on flat at back end left hand side of crown.					

NOTE.—Measurements to determine the linear extension showed that there was none.

This furnace had been annealed as the last process of manufacture; the annealing process being performed by uniformly heating to low cherry red, and allowing the furnace to cool gradually in the open air. This is the same process followed with all Fox's furnaces before delivery.

MECHANICAL TESTS OF MATERIAL.

TENSILE TEST OF SIX SPECIMENS CUT FROM THE PLATE FROM WHICH THE ABOVE NUMBERED FLUE TUBE WAS MADE.

Test No.	Marks on piece.	Dimensions.			Limit of Elasticity.		Breaking load.		Extension on 10″, per cent.	Reduction of area, per cent.	Ratio of limit to break.	Extension on 10″ at		Remarks.
		Broad.	Thick.	Area.	Pounds per sq. inch.	Tons per sq. inch.	Pounds per sq. inch.	Tons per sq. inch.				40,000 per sq. inch.	50,000 per sq. inch.	
Not annealed.														
17,770 B	2,571 P. S.	1.488	.445	.662	45,870	20.48	65,520	29.26	19.0	50.4	.700	.05	.23	Silky.
17,771 B	A 419	1.488	.450	.670	44,960	20.07	64,920	28.99	23.5	49 8	.692	.03	.24	Silky.
17,772 B	...	1.492	.445	.664	45,750	20.43	64,470	28.78	22.5	49.2	.710	.04	.25	Silky.
Average.	...	...	...	...	...	20 33	...	29.01	21.7	49.8	...	...	...	
Annealed.														
17,773 B	2,571 P. S.	1.494	.437	.653	38,590	17.23	57,110	25.50	24.6	55.5	.676	.34	.73	Silky, slightly laminated.
17,774 B	A 419	1 496	.445	.666	39,560	17 66	56,210	25.10	24.0	54.7	.704	.28	.67	Silky, slightly laminated.
17,775 B	...	1.496	.436	.652	39,970	17.84	58,920	26.31	20.2	54.5	.678	.03	.45	Silky, considerably laminated.
...	...	...	...	...	...	17.58	...	25.64	22.9	54.9	...	...	...	

MEASUREMENTS FOR THICKNESS.

...	...	...	...	...	...	17.50	...	25.04	22.9	54.9	...	...	...

MEASUREMENTS FOR THICKNESS.

Number of test hole.	Front.	Middle.	Back.
1 weld.	.461	.505	.489
2	.464	.453	.437
3	.463	.470	.456
4	.478	.5	.473
5	.480	.470	.450
Mean of unwelded plate.	.471	.473	.454

Mean thickness of front end, .471; middle, .473; back end, .454. Mean thickness of the plate, .466.
Mean thickness of the welded portion of the plate, .485, being .0475 greater than the mean thickness of the unwelded plate. Mean thickness of the unwelded plate, .466, and .0285 greater than the nominal thickness.

COMPRESSIVE TESTS OF SIX SPECIMENS CUT FROM THE PLATE FROM WHICH THE ABOVE NUMBERED FLUE TUBE WAS MADE.

Test No.	Marks on piece.	Dimensions. Broad.	Thick.	Area.	Breaking load. Pounds per sq. inch.	Tons per sq. inch.	Compression on 10″ at 30,000 per sq. inch.	40,000 per sq. inch.	Remarks.
Not annealed.									
17,776 B	2,571 P. S.	1.503	.453	.681	44,610	19.92	.01	.015	Gave away by buckling without cracking in all cases.
17,777 B	A 419	1.513	.453	.681	43,920	19.61	.01	.02	
17,778 B	...	1.500	.442	.663	44,300	19.78	.015	.02	
Average,	...	...	...	...	44,277	19.77	.012	.018	
Annealed.									
17,779 B	2,571 P. S.	1.500	.438	.657	35,700	15.94	.015	...	
17,780 B	A 419	1.500	.438	.657	39,780	17.76	.02	...	
17,781 B	...	1.500	.443	.665	36,100	16.12	.02	...	
Average,	...	...	...	...	37,193	16.61	.018	...	

TENSILE TESTS MADE FROM PORTIONS OF THE CORRUGATED FLUE TUBE AFTER THE COLLAPSING. TEST HAD BEEN COMPLETED. TEST PIECES CUT FROM VARIOUS PORTIONS IN EACH TUBE.

Test No.	Marks on piece.	Dimensions. Broad.	Thick.	Area.	Limit of elasticity. Pounds per sq. inch.	Tons per sq. inch.	Breaking load. Pounds per sq. inch.	Tons per sq. inch.	Ratio of limit to break.	Extension in 10″, per cent.	Reduction of area, per cent.	Extension on 10″ at 30,000 per sq. inch.	40,000 per sq. inch.	50,000 per sq. inch.	Remarks
18,502	2,571 P. S.	1.498	.475	.712	44,570	19.90	62,980	28.11	.708	20.9	53.5	.02	.05	.20	Silky.
18,503	...	1.500	.500	.750	36,740	16.40	64,950	29.00	.566	24.0	53.2	.05	.10	.29	Silky.
18,504	...	1.495	.460	.688	45,440	20.29	64,100	28.62	.709	24.6	47.7	.00	.02	.24	Silky.
Average,	...	...	...	...	42,250	18.86	64,010	28.58	.661	23.2	51.5	.02	.06	.24	

Tests of the material made by Prof. Alex. Kennedy, at his testing works, 19 Little Queen street, Westminster. Copied from report made to T. W. Traill, Esq., the Engineer Surveyor-in-Chief to the Board of Trade. Copy supplied to the Leeds Forge Co., Limited, Leeds, by Board of Trade, memo. E. S. C., 4571, 90.

CORRUGATED FLUE TUBE.—TESTED AT LEEDS FORGE, NOV. 4 AND 5, 1890.

NOMINAL THICKNESS NINE-SIXTEENTHS INCH. No. 2,623.

	Measurements taken at A No. 1.		Measurements taken at B No. 6.		Measurements taken at C No. 11.	
	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.
Dimensions taken before test.	2′ 7$\frac{31}{32}$″	2′ 7$\frac{30}{32}$″	2′ 7$\frac{31}{32}$″	2′ 7$\frac{31}{32}$″	2′ 7$\frac{31}{32}$″	2′ 7$\frac{31}{32}$″
Pressure in pounds per square inch.	Movement.		Movement.		Movement.	
200	Nil.	Nil.	Nil.	Nil.	Trace in	Nil.
300	Trace in	"	"	"	$\frac{1}{16}$ trace in	"
400	$\frac{1}{16}$ in	"	Trace in	"	$\frac{1}{16}$ in	"
500	"	"	"	Trace in	$\frac{1}{16}$ full	"
600	$\frac{1}{32}$ in	"	$\frac{1}{16}$ full in	"	"	"
700	"	"	"	"	$\frac{1}{16}$ full in	"
800	$\frac{1}{32}$ full	"	$\frac{1}{32}$ in	"	"	Trace out
Pressure released to 0.	...	"	...	No set.	...	...
900	$\frac{1}{16}$ in	Trace out	$\frac{1}{32}$ full in	Trace in	$\frac{1}{16}$ full in	Trace out
1,000	$\frac{1}{16}$ full in	"	"	"	$\frac{1}{32}$ b. in	$\frac{1}{16}$ out
1,100	"	"	"	"	$\frac{1}{32}$ f. in	"
1,200	$\frac{1}{32}$ f. in	"	$\frac{1}{16}$ f. in	"	"	"
Pressure released to 0.	Set $\frac{1}{16}$ in	No set.	T. of set in	No set.	$\frac{1}{16}$ set in	No set.
1,400	Measurements at this pressure not taken.				Pressure released to 0 for caulking of rivets.	
Pressure released to 0 after 1,400.	Set $\frac{1}{32}$ in	$\frac{1}{64}$ set in	$\frac{1}{16}$ set in	$\frac{1}{16}$ set out	$\frac{1}{16}$ b. set in	No set.
1,400	Slight collapse at corrugation No. 11 on the weld.					

NOTE.—Measurements to determine the linear extension showed that there was none.

MECHANICAL TESTS OF MATERIAL.

TENSILE TESTS OF SIX SPECIMENS CUT FROM THE PLATE FROM WHICH THE ABOVE NUMBERED FLUE TUBE WAS MADE.

Test No.	Marks on piece.	Dimensions. Broad.	Thick.	Area.	Limit of elasticity. Pounds per sq. inch.	Tons. per sq. inch.	Breaking load. Pounds per sq. inch.	Tons per sq. inch.	Ratio of limit to break.	Extension on 10″, per cent.	Reduction of area, per cent.	Extension on 10″ at 40,000 per sq. inch.	50,000 per sq. inch.	Remarks.
Not annealed.														
17,815 E	2,623 P. S.	1.487	.564	.839	44,550	19.89	63,940	28.55	.697	20.9	43.5	.07	.27	Silky, a roll flaw on surface.
17,816 E	A 419	1.488	.562	.836	39,200	17.50	63,450	28.34	.617	21.9	48.2	.11	.30	Silky, very slightly laminated.
17,817 E	...	1.490	.560	.834	43,080	19.24	64,430	28.77	.669	25.5	49 4	.04	.22	Silky.
Average,	...	...	...	...	...	18 88	...	28.55	...	22.8	47.0	...	...	
Annealed.														
17,818 E	2,623 P. S.	1 494	.556	.831	40,450	18.06	58,560	26.15	.691	21.8	*	.04	.60	Silky, slightly laminated. †
17,819 E	A 419	1.488	.556	.827	40,030	17.87	61,160	27.30	.655	23.7	52 9	.06	.52	Silky.
17,820 E	...	1.490	.550	.820	40,090	17.90	62,630	27.96	.640	22.0	46.3	.04	.49	Silky, a roll flaw on surface.
...	...	...	...	...	...	17.94	...	27.14	...	22.5	49.6	...	...	

*Too irregular to measure. †Surface covered with bad roll flaws.

MEASUREMENTS FOR THICKNESS.

17,820 E	...	1.490	.550	.820	40,990	27.90	62,630	27.96	.640	22.0	46.3	.04	.49	Silky, a roll flaw on surface.
...	...	...	...	...	...	27.94	...	27.14	...	22.5	49.6	...	...	

* Too irregular to measure. † Surface covered with bad roll flaws.

MEASUREMENTS FOR THICKNESS.

Number of test hole.	Front.	Middle.	Back.
1 weld.	.632	.714	.587
2	.586	.615	.575
3	.572	.575	.598
4	.578	.598	.577
5	.572	.563	.524
Mean of unwelded plate.	577	.585	.551

Mean thickness of front end, 577: middle, .585: back end, .551. Mean thickness of the plate, .571.
Mean thickness of the welded portion of the plate, .644, being .0815 greater than the mean thickness of the unwelded plate. Mean thickness of the unwelded plate .571, and .0085 greater than the nominal thickness.

COMPRESSIVE TESTS OF SIX SPECIMENS CUT FROM THE PLATE FROM WHICH THE ABOVE NUMBERED FLUE TUBE WAS MADE.

Test No.	Marks on piece.	Dimensions. Broad.	Thick.	Area.	Breaking load. Pounds per sq. inch.	Tons per sq. inch.	Compression on 10" length at 30,000 per sq. inch.	40,000 per sq. inch.	Remarks.
Not annealed.									
17,821 E	2,623 P. S.	1.492	.564	.841	36,420	16.26	.01	...	Gave way by buckling without cracking in all cases.
17,822 E	A 419	1.494	.568	.849	35,630	15.91	.015	...	
17,823 E	...	1.494	.568	.849	37,530	16.76	.02	...	
Average,	...	...	...	...	36,527	16.31	.015	...	
Annealed.									
17,824 E	2,623 P. S.	1.497	.557	.834	37,870	16.91	.02	...	
17,825 E	A 419	1.494	.557	.832	39,970	17.84	.015	...	
17,826 E	...	1.494	.567	.847	36,720	16.40	.02	...	
Average,	...	...	...	...	38,187	17.05	.018	...	

TENSILE TESTS MADE FROM PORTIONS OF THE CORRUGATED FLUE TUBE AFTER THE COLLAPSING TEST HAD BEEN COMPLETED. TEST PIECES CUT FROM VARIOUS POSITIONS IN EACH TUBE.

Test No.	Marks on piece.	Dimensions. Broad.	Thick.	Area.	Limit of elasticity. Pounds per sq. inch.	Tons per sq. inch.	Breaking load. Pounds per sq. inch.	Tons per sq. inch.	Ratio of limit to break.	Extenson on 10", per cent.	Reduction of area, per cent.	Extension on 10" length at 30,000 per sq. inch.	40,000 per sq. inch.	50,000 per sq. inch.	Remarks.
18,511	2,623 P. S.	1.495	.661	.988	39,980	17.85	43,240	19.31	.924	1 9	3 4	.0	.20	...	Very finely crystalline*
18,512	...	1.495	.619	.925	40,660	18.16	47,850	21.36	.850	5.0	16.3	.0	.05	...	Finely granular.†
18,513	...	1.495	.640	.957	38,560	17.21	48,800	21.79	.790	5.1	12.2	.0	.04	...	Irregular.‡
Average,	...	...	...	...	39,733	17.74	46,630	20.82	.855	4.0	10 6	.0	.10	...	

* About 10 per cent. granular, a large flaw, broke through weld. † About 20 per cent. crystalline, granular, with a large flaw, broke through weld. ‡ 60 per cent. silky, 20 per cent. granular, a large flaw, broke through weld.

Tests of the material made by Prof. Alex. Kennedy at his testing works, 19 Little Queen street, Westminster. Copied from report made to T. W. Traill, Esq., the Engineer Surveyor-in-Chief to the Board of Trade. Copy supplied to the Leeds Forge Co., Limited, Leeds, by Board of Trade, memo. E. S. C., 4571, 90.

NOTES.

"SMOKE."

[Extract from a paper read by Mr. William Metcalf before the Engineers' Society of Western Pennsylvania.]

In dealing with a subject of such universal interest as smoke, engineers will pardon me for an elementary statement of the conditions of combustion, which is necessary for the information of any general readers who may wish to read our discussion of the matter.

The combustion of coal involves two processes: first, the conversion of the carbon to the condition of gas or vapor, and second, the union of the carbon with the oxygen of the air. This union produces the intense heat so familiar to us all, and the product of combustion, when complete, is carbonic acid. In addition to this carbonic acid, water is produced by the burning of any hydrogen that may be in the coal. Any sulphur in the coal is burned to sulphurous or sulphuric acid, and any other combustibles are burned to their several oxides.

All of this seems very simple, and it is simple enough until we attack the principal part of it. The difficulty of mixing the gases to produce perfect combustion is so great as to be practically impossible; if we burn all of our carbon to carbonic acid we have inevitably a large excess of air going through our fire, and if we do not burn it all to carbonic acid in the few moments at our disposal in the furnace, there is a deficiency of air, and the excess of carbon is wasted in the form of carbonic oxide, half burned carbon or in vaporized carbon which is thrown off with great rapidity in the dense black vapor which we call smoke.

In the intense heat of a fiercely burning fire our bituminous coal is vaporized with such great rapidity that it is impossible, practically, to burn it all before it flies to the chimney and passes beyond the reach of combustion, but much may be done by steady, mechanical firing in small quantities at a time, to reduce

the smoke nuisance, where the most intense heat is not necessary, and where other and more important matters do not make other methods of firing imperative. A flame of perfect combustion is not white; it is blue, or a bluish-white, somewhat of the color of the arc-light. Such a flame is not a good radiator of heat, and is, therefore, not so efficient for heating or melting purposes as the cooler white flame of imperfect combustion, which we know as the radiating flame. The carbonic acid non-radiating flame is excessively destructive; its cutting power on anything with which it comes in contact is amazing when we see a furnace of the best refractories cut down and ruined in a few hours, which would endure a steel melting heat for many weeks or months if it were subjected to a white radiating flame only.

Many of us know, to our heavy cost and intense disgust, how easily a careless or ignorant man can so burn up in a short time hundreds of dollars worth of the highest refractories, and lay the whole plant idle for repairs. We cannot produce the soft, white radiating flame without some smoke, because we can not attain an exact balance of the gases, and therefore to maintain such a flame we must have a deficit of air, a surplus of carbon and some smoke.

In operating a reverberatory furnace for melting, puddling or heating, the smallest loss from the perfect combustion flame is caused by the destruction of the furnace; the furnace contains in its charge of iron and steel something of far greater value than the firebricks, and the terrible oxidizing power of that flame can only be realized by those who have to wonder where their iron has gone, and to wonder why their losses in operating are so great and their profits are so small. Meanwhile the gentle "dickey bird" sits aloft on the blast furnace and whistles to himself softly as his neighbor's losses come up the elevator in the shape of cheap ore. People call it slag; the bird sings ever so gently "no smoke," "use coke." There is no smoke from a blast furnace because coke is used, but the vapors of a blast furnace are far more deadly than smoke, only they are white and so they do not count.

A beautiful illustration of the effects of the two flames we

have been discussing may be seen by watching a puddler's operations. When he has scrap-balls to cut down to make bottom, he rushes up his fire, pulls his damper wide open and draws in a great surplus of air. In a few minutes the little ends of the scrap glow white, and presently little molten globules may be seen dropping off here and there; they increase in number and in size until little streams are running down the pile; the whole pile is dripping, and fades away to a last little lump, which the puddler pulls out because it would be a waste of time to cut it down. Melted iron? Not a drop; his furnace is never hot enough to melt wrought iron; it is melted oxide of iron; the iron burned up.

The bottom finished and set, he goes on with the well-known operations of melting and boiling until his iron comes to nature; and now how different are his motions; the damper is adjusted to a nicety, a little more fuel is added, until there is a surplus of carbon and a deficit of air; he gathers up the little grains and sticks them together into little balls, and these into larger balls, turning them repeatedly, keeping them covered with slag to prevent oxidation from any possible surplus of air or carbonic acid; and so, quickly and carefully, he makes up the balls to the right size and rushes them out of his furnace to the squeezers or hammer.

Any oxidation now means loss of iron, and consequent loss of wages, and hard toil wasted.

Don't let him make any smoke, though; what matter if his well-earned wages do burn up, provided we may have clear skies and, I was going to add, pure air. But we will come to that question later.

With natural gas, the common puddling and heating furnaces do not make much smoke, but the awful waste of gas is a sin for which Pittsburgh is paying dearly now, and must continue to pay for many years to come.

When we come to the regenerative furnaces, one would say, naturally, here at least there is no excuse for smoke; many of us thought so, and many of us tried it. I have seen hundreds of valuable crucibles cut down, and the furnaces cut down and

destroyed, in the beautiful blue-white, perfect-combustion flame, and yet the steel in the crucibles was not melted properly.

Tons upon tons of iron and steel have been wasted away in the same beautiful flame, and yet the masses were not heated through nor in condition to be worked. Now, the invariable rule is, you must have a smoky stack, and the evidence of a well-run plant is that the stacks do smoke. It is a little odd, at first sight, that in these furnaces natural gas makes a little denser smoke than producer-gas, but there is nothing singular about it when we reflect that it contains about four times as much carbon as producer-gas.

The most persistent smoker is the boiler, and the reason is obvious; there are no hot walls there to radiate back the heat, or to aid combustion. The very object of the boiler is to destroy the fire, and rob it of its heat as quickly as possible; therefore every particle of gas that comes unburned into contact with the boiler shell must float up the stack unburned, surplus of air or not, and add to the volume of smoke. The ordinary boiler fire goes through three stages: The freshly fed, when it pours out dense volumes of the blackest smoke, and carries what heat there may be up the stack and there is very little steam raised; the good-burning stage, when there is a glorious fire, the boiler steams tremendously and at dangerous speed, and there is but little smoke; the perfect-combustion stage, when there is a beautiful clear fire, no smoke, and the surplus air is rushing along and carrying off so much heat that the water begins to rise and the steam to fall.

Then the weary fireman opens his doors, rattles out his ashes, shovels in another cartload of coal, shuts up his doors and lets her smoke, while he sits down to wipe off the sweat, and, if he is a sensible fellow, to smoke a little himself.

Why not use producer or water gas, and prevent the smoke, even if there is a little excess of air; there is no glowing iron nor delicate steel to cut down here? It has been tried in England, Scotland, Germany, and even among the patient Dutch. They all gave it up, Dutch and all; and even here, in Pittsburgh, we

tried it at an expense of thousands of dollars, and we thought we had it, but we were all mistaken.

Is there no remedy, then? Yes, a partial one. The first stage can be eliminated entirely by good, automatic stokers; but then the second stage of fierce firing cannot be reached, and, on the whole, probably more boilers would be required. That was the experience thirty years ago with the Meisner grate, probably as good a one as any of the more modern stokers; but that in the end would not be a hardship, because the more moderate and even firing would be so much easier on the boilers that the reduced repair bills would probably more than balance the interest on the increased cost. But these automatic stokers do smoke just a little, and they keep it up, so that our nuisance is only lessened, not abated.

With natural gas boilers may be fired smokelessly when gas is plenty. The favorite way with gas companies is, or was, to furnish two or three pounds of gas; a whole lot of squirt guns, called air mixers, a lighted match, and then let her rip. Oh, how delighted they are, or were, with their perfect combustion and their smokeless fires! and oh, how they swore when they saw their big millions of feet consumed and their little piles of dollars received! There are, or were, no meters under the boilers.

The boilers under my charge were fired that way at first, and the way they roared and rattled and vibrated and perfect combusted and didn't make steam, was a sight to behold once in a lifetime.

And the way I shook and trembled with fear while that was going on, was an experience to be endured not more than once in a life.

After an expenditure of much time, some thought and considerable money, a partially regenerative fire was adopted by which, with from two and a half to three ounces of gas, we can keep steam up nicely; but singularly, when the gas is very low, when every atom seems necessary, then, to keep up steam at all, we must exclude any surplus air so thoroughly that now our boiler

stacks smoke a little, only a little; still they do smoke, and so the evidence of the best practice again is a little smoke in the stack.

The next thing to consider is, what do we lose by smoke?

There are smoke-consuming devices advertised claiming savings in fuel of from 10 to 25 per cent.

The best authorities I know of give the extreme of loss from smoke as 5 per cent., and the mean loss from average firing as 2 per cent.; therefore, if the devices mentioned do save from 10 per cent. to 25 per cent. of fuel, they are misnamed. Instead of being called smoke consumers, they should be named heat savers. That such saving over ordinary wasteful methods can be made there is no doubt, and if in doing so they save 5 per cent. that goes as smoke, so much the better, provided that in furnace firing they do not burn up ten times this value in iron or steel, or valuable refractories, or all three together.

NAVY BOILERS.

[Editorial in London "Engineering," March 18th, 1892.]

On Monday last, the first instalment of the year's Parliamentary talk on the Navy took place in the House of Commons with rather less than the usual result, only one vote being passed, namely, that which provides for the wages of the 74,100 of all ranks which are set down as being necessary for sea and other services of the Navy during the forthcoming year. We are used to getting our naval matters in snippets now. We get the First Lord of the Admiralty's explanatory statement, which tells us something, and then await further developments. Next, the Navy estimates, so called, arrive; but the first thing that catches one's eye is a printed slip stating that: "A complete copy of the Navy estimates, including the programme of shipbuilding and appendices, will be printed and circulated separately." So we wait again. Then comes the debate in the House, of course very embryotic with its one vote. One debate one vote; at which proportion it would require sixteen debates to dispose of the whole of the estimates. Another fragment comes in the shape of the official report on the naval manœuvres; perhaps Mr. White will read a paper before the Institution of Naval Architects on the designs of the new battle-ships, or some other semi-

official exposition of naval policy. That would be a very welcome fragment. There was a talk of the engineering branch of the controller's department contributing a paper on recent navy boiler designs at the forthcoming meeting of the Institution of Naval Architects, but nothing more has been heard of this lately, and doubtless it has been shelved in view of the formation of the enlarged boiler committee which is to be presided over by Admiral Buller. That, however, is likely to be rather a big thing, certainly more than a fragment, unless the public part is suppressed by the inquiry being held *in camera*.

The one vote passed, as we have said, was for the *personnel* of the Navy, the estimated cost of which is £3,520,000. Members, however, by no means confined themselves to the question of *personnel* in discussing the vote; otherwise we should have little or nothing to say on the subject, for the great question of manning the Navy, paramount as is its importance, can hardly occupy a space in our columns, excepting so far as the engineering branch of the service is affected. Admiral Mayne was the first to broach the great boiler question, which has been in the minds of so many during the last twelve months. To Admiral Mayne the present condition of affairs with regard to boilers is a complete triumph; although we have no doubt the gallant admiral, as a patriotic Briton and a good naval officer, deplores the condition of affairs as much as any one. Admiral Mayne sometime ago described "forced draft" as an invention of the Evil One; though why the Prince of Darkness should wish to neutralize the mightiest weapons of human destruction is a question we will leave to Mr. Morton, as being more in his line than ours. At any rate, the phrase has become historical, and, in the light of recent experience, we can well understand naval officers, who are not engineers, subscribing to it. It will be remembered that forced draft was first applied in ships of very considerable size belonging to the Royal Navy, on board H. M. S. S. *Satellite* and *Conqueror*. The former vessel is a sloop, and has low cylindrical boilers with straight-through tubes, and an intermediate combustion chamber. The *Conqueror*, however, as every one knows, is an ironclad, and has return-tube boilers. Some details

of these trials will be of interest just now, but for full particulars we must refer our readers to Mr. Butler's paper read before the Institution of Naval Architects in 1883. The *Conqueror* had eight return-tube boilers, six being flat-sided and two circular. There were three furnaces in each boiler, so that they were of the single-ended type. The total grate area was 585 square feet, and the total heating surface was 13,340 square feet, of which 11,050 square feet were in the tubes, which were of brass. A forced-draft trial was made with only four boilers in use, the air pressure being 1¾ inches on the water gauge. The mean steam pressure by the engine-room gauge was 63 lbs., and there was developed 4,023 indicated horse power. The area of fire grate in use was 300 square feet, which gave 13.41 indicated horse power per square foot of grate, as against 7.96 indicated horse power per square foot of grate when running at 64 lbs. pressure, with the natural draft for which the machinery was originally designed. In the forced-draft trial the tube surface per indicated horse power was 1.41 square feet, the total heating surface per indicated horse power being 1.71 square feet. On the natural-draft trial the corresponding figures were 2.37 and 2.86 respectively. Other forced-draft trials were made. The ratio of fuel consumption was not given in the paper. The result of these trials was looked on as very favorable to the prospects of the forced-draft system, and in the concluding passage of his paper Mr. Butler said, in summing up the advantages of forced draft: "These numerous points are collectively of sufficient importance to entitle such an extension of this system, in my opinion, to consideration." That evidently and very properly, was the opinion of the Engineering department of the Admiralty; in fact Mr. Butler's paper had practically all the weight of an official statement, as its reading was sanctioned by the Board, the author being then, as now, an official in the Government service. Before we leave this paper, however, there is one further quotation from it we will make. "With regard to the endurance of the boilers, there can be no doubt that the frequent use of forced draft would produce a great diminution in the life of those parts subject to the intense heat. But probably under the conditions

that will obtain, this will not be a serious moment. An examination of the boilers of the *Satellite* and *Conqueror* after the trials showed that they had not suffered to an unusual extent by the exposure to the intense heat for the short time the trials lasted. Only two or three of the iron tubes were found to be weeping in the low boilers, and in the *Conqueror's* a few seams and rivets and about twenty of the tubes were leaking slightly." Those few seams and rivets and about twenty tubes leaking slightly were the small cloud which has gathered since into so black a storm, to burst on the devoted heads of the present engineering staff at the Admiralty.

It was not for a time that the trouble came. Mr. James Wright, now Sir James Wright, was then Engineer-in-Chief, but a little time after he retired and was succeeded by Mr. Richard Sennett, an engineer who had been brought up in the service, and was undoubtedly a man of great ability and high attainments. To the sorrow of every one who knew him, Mr. Sennett died a short time ago, but his memory has no need to be shielded under the *De mortuis* maxim. Nevertheless, Mr. Sennett made a mistake. He was zealous and ambitious; zealous that the ships of the Royal Navy should exceed all others, in speed at any rate; which was the chief factor that he could influence. He found to his hand a most potent weapon for his purpose; and with a courage we cannot but admire, although the result has proved disastrous, he pushed forced draft beyond its legitimate scope. There were, however, many things to lead Mr. Sennett astray, as we can now see speaking after the event, when it is so easy to be wise, and in the light of fuller knowledge. In the year 1888, five years after the reading of Mr. Butler's paper, another paper on forced draft was read before the Institution of Naval Architects by a very able engineer, who has since left the Government service and taken a high position in a private firm, as Mr. Sennett himself did before his death. This paper was by Mr. Thomas Soper, and in it he says: "At that time (*i. e.*, when Mr. Butler read his paper in 1883), it was apprehended in some quarters that, although the closed stokehold system had the great advantage of considerably increasing the

evaporative power of the boilers, experience would prove that their durability would be diminished. The system has now had a trial lasting over some years, and it is found that the boilers of vessels fitted with the forced draft are in quite as good a condition as those which are worked with natural ventilation only." Further on Mr. Soper said: "Those who are acquainted with the method of conducting admiralty trials, know that the boilers are more severely tested during the official forced draft trials, which are usually when machinery is received from the contractors, than is likely to be experienced afterwards. Yet the experience of the receiving officers at the dockyards proves that the condition of the boilers after such a trial is, as a rule, much better than in the old days when the steam blast was used." Evidently then the storm had not burst, but the admiralty engineers and the contractors were not without their trouble. In two or three vessels of the *Archer* class the boiler tubes leaked, but this was not thought to be due to forced draft, and on the other hand the *Porpoise* had made a ninety-six hours' forced-draft trial with most satisfactory results.

At that time the cruisers *Australia* and *Galatea* had made their trials, and in fact were, with their sister belted cruisers, the largest vessels in the Navy, which, up to that time, had made their trials with triple-expansion engines and forced draft. Now, these two ships are notable from the fact that they were fitted with double-ended boilers, having three furnaces at each end and but one combustion chamber, common to the whole six furnaces. The machinery of these vessels, as will be remembered, was designed by Mr. A. C. Kirk, now Dr. Kirk, Messrs. Napier being the contractors. It is also noteworthy that four sister vessels, the *Orlando* and *Undaunted*, engined by Messrs. Palmer, and the *Narcissus* and *Immortalite*, engined by Earle's Company, had one combustion chamber to each opposite pair of furnaces. For the present it is sufficient to say that the *Australia* and *Galatea's* boilers gave the best results. In fact, these vessels, fitted with the now never sufficiently-to-be abused double ended common combustion chamber boilers, made as successful trials as any ever run in the Navy. There are many

who remember the enthusiastic way in which Mr. Kirk was cheered by his men at the conclusion.

The following particulars of the machinery of these vessels may be of interest:

	Australia.	*Galatea.*
Diameter of boiler, external	14 feet 8½ inches.	14 feet 8½ inches.
Length of boiler, external	16 feet 9 inches.	16 feet 9 inches.
Fire grate area, total	500 square feet.	500 square feet.
Length of grate	5 feet 8 inches.	5 feet 8 inches.
Tube surface, total (iron tubes)	13,480 square feet.	13,480 square feet.
Length of tubes	6 feet 5½ inches.	6 feet 5½ inches.
Diameter of tubes	2⅜ inches.	2⅜ inches.
Pitch of tubes	3¼ inches.	3¼ inches.
Mean indicated horse power during four hours trial	8,876	9,219
Maximum indicated horse power for one-half hour	9,130	9,653
Steam pressure in boilers (mean)	132 pounds.	138 pounds.
Air pressure in stokeholds	1.75 inches.	1.15 inches.
Indicated horse power per square foot grate (mean)	17.75	18.44
Indicated horse power per square foot grate (maximum)	18.26	19.30

We believe that on the *Australia's* forced draft trial, the coal burnt per square foot of grate was close upon 43½ pounds per hour.

Mr. Kirk, speaking in 1888 on the subject of forced draft, said: "In the case of Admiralty boilers even going up to 2 inches of water pressure, where the boilers have been managed with any reasonable care, they have stood the test, and that for a lengthened period, too, quite successfully. * * * With reference to the advantages of a combustion chamber, first of all let me remark that I think it is a thing which has long been known in the profession, that the smaller the grate you can burn your quantity of coal on in a given boiler, the more economical will be your working. * * * No doubt the single combustion chambers in the *Galatea* were a very good thing, and they fulfilled the the purpose they were intended for very well, indeed; but that was not altogether on account of their cubic capacity, but because they allowed of a better admixture of gases, and thus

prevented the cold current of air that went in when the door was opened, from having its effects localized, instead of which the cold air was diffused amongst the hot gases coming from the other furnaces." These remarks of one of the very first engineers of the period are worth noting, although we believe Mr. Kirk had not in his thoughts the subject of leaky tube ends, as that question had not then so much exercised the minds of engineers.

The second-class cruisers of the *Medea* or "M" class were the first that attracted popular attention on account of troubles resulting from the pressure on trial trips. The *Medea* has four double-ended cylindrical return-tube boilers with a common combustion chamber, across the middle of which, extending from top to bottom, a firebrick division has been built. The diameter is 12 feet 2 inches, and the length 18 feet 2 inches. There are three furnaces at each end, or twenty-four in all boilers. They are of the corrugated type, and have a mean diameter of 3 feet 1½ inches. The grate area is 525 square feet, and the heating surface of the tubes is 12,096 square feet, and of the furnaces 1,584 square feet, giving a ratio of heating surface to grate surface of 26.1 to 1. There are 2,808 tubes, of which 688 are stay tubes, the diameter being 2½ inches and the length between tube plates 6 feet 7 inches. On the forced-draft trial of the *Medea* the indicated horse power was 9,185; the air pressure was close upon 2¼ inches, and the steam pressure 149 pounds per square inch. The engines are three stage compounds, having cylinders 33½ inches, 49 inches and 74 inches by 3 feet 3 inches stroke. The revolutions were 139.45 per minute. On the *Medusa's* trial, a sister ship, the indicated horse power was 9,435. There is no need here to say anything about the performance of the boilers of these ships beyond the fact that on the whole they could not be pronounced altogether successful. The *Marathon* and *Magicienne* were ships of the same class, but somewhat larger, although their machinery was designed to give the same horse power, namely, 9,000 indicated. These vessels had each four double-ended, cylindrical, common-combustion-chamber boilers, each with six furnaces, and a firebrick partition was

erected so as to separate the two ends. There were 2,528 tubes (520 stay tubes), 2½ inches in diameter and 7 feet 3½ inches long. The length of the fire grate was 7 feet 4 inches and the area 535.4 square feet. The total heating surface was 13,471 square feet, 11,771 square feet being tube surface. The engines were horizontal three-stage compound, with cylinders 34½ inches, 51 inches and 76½ inches by 3 feet stroke. The *Marathon*, on her forced-draft trial, worked with an air pressure of 2.37 inches on the water gauge. The steam pressure was 146 pounds to the square inch, the revolutions 144.03 per minute and the indicated horse power 8,785. With natural draft the revolutions were 132.19 and the indicated horse power 6,205. The *Magicienne*, on her forced-draft trial, had an air pressure of 2.2 inches, and steam pressure of 147.87 pounds to the square inch. The revolutions were 143.57 per minute, and the indicated horse power 9,280.

We now come to a more modern vessel which has proved a sad disappointment, her boilers breaking down entirely on trial. The *Vulcan* has four cylindrical double-ended return-tube boilers 14 feet 1 inch in diameter by 17 feet long. They have the common combustion chamber and the brick wall between. There are 3,688 tubes (856 being stay tubes) 2½ inches in diameter. There are twenty-four furnaces 3 feet 7 inches in diameter. The length of grate is 7 feet and the area 600 square feet. The heating surface is 17,488 square feet, of which 15,688 square feet is tube surface. The *Vulcan* has also a single-ended auxiliary boiler of the return-tube type, with three furnaces. The diameter is 12 feet 5 inches. The *Vulcan*, Lord George Hamilton says in his statement, passed an eight-hours' natural draft trial most satisfactorily; but in carrying out a series of progressive trials with lower powers and pressures there was serious leakage in the tubes of two boilers. In the *Thunderer*, which was reboilered on a similar plan, we are told that the experience was similar.

There is no need at present to refer to recent trials of other vessels, either successful or unsuccessful. We have no wish to add to the feeling of disappointment, not to say alarm, which is

now felt on account of the failure of the machinery on our war vessels. A good many exaggerated statements have undoubtedly been made and injustice done to public servants whose mouths are closed by virtue of their position, however false may be the accusation brought against them, or unjust the blame laid on their shoulders.

The particulars above given will enable engineers to form some slight comparison between the boilers similar in type of successful and unsuccessful vessels. We do not pretend to account for the mishaps that have occurred; that would require a far wider knowledge than can be gained by any one outside the official circle, and even with all advantages of information it would appear that the problem is not to be solved at once. At the same time there are certain points worth considering, and these we may refer to later. A searching inquiry by an able committee such as that recently formed, containing such experts as Mr. Robert Humphreys, Mr. Milton, Mr. Manuel, and others whose names have not yet been mentioned, should arrive at some conclusion, supposing all facts are unreservedly put forward, and there is no reason to suppose that any other course will be followed. It is to be hoped that the public will be permitted to benefit by the labors of the committee.

EFFECT OF DEPTH OF WATER ON SPEEDS OF SHIPS.

[Extract from paper of W. H. WHITE, ESQ., Director of Naval Construction, British Navy, read before the Institution of Naval Architects at the spring session, 1892.]

Several references have been made to this matter in the foregoing remarks. It is well known that shallowness of water exercises a retarding effect on steamships. Until very high speeds were aimed at the question assumed small importance. Under present conditions it is in an altogether different position. I do not now propose to attempt any investigation into the causes which produce retardation or influence its amount, although these subjects have naturally occupied my mind and must be dealt with. A few facts out of many available will be put on record.

Two sister vessels of the torpedo-gunboat type, of shallow

draught, were run, one at half tide and one at low tide, over the Maplin measured mile. The difference in depth of water on the two trials was about 9 feet on 42 feet. With the same power indicated one vessel attained 17 knots at low tide and the other 17½ knots at half tide.

Another vessel of the class was tried over the measured mile near the Tyne at high water and at low water. During one run she attained 17.8 knots at high tide, with about 2,800 horse power; at low tide she attained 16.9 knots, with about 2,600 horse power. Here also the loss in speed was fully half a knot in the shallower water, allowing for difference of power.

The *Edgar*, in Stokes Bay, with 12 fathoms of water, required 13,260 horse power to attain 20½ knots. In water 30 fathoms deep, between Plymouth and Falmouth, she reached practically 21 knots with 12,550 horse power. This represents a loss of about ¾ knot speed due to shallowness of water; or, putting it in another way, in deep water the *Edgar* would attain 20½ knots with 1,500 horse power less than was required in Stokes Bay. That measured mile is the best we have for running Her Majesty's ships on the south coast. It is a matter of common experience that when a ship enters the mile from the Cowes end and runs over the shallows her speed is sensibly diminished, as compared with her condition when she runs on from deep water at the Spithead end. These circumstances tell much against high-speed ships, as compared with the conditions of a deep-water mile like that at Skelmorlie.

In the trials of the *Latona* at Stokes Bay, and of the *Terpsichore* at Skelmorlie, it appeared that the greater depth of water gave an advantage of about $\frac{4}{10}$ knot in speed, or about 600 horse power.

My last illustration is taken from the eight-hours' trial of the *Blenheim* when running from the Nore to Portsmouth. It has already been explained that the log speeds were proved to be fairly accurate in this case. In the first hour the vessel was traversing most of the time water about 9 fathoms in depth. The engines made about 92½ revolutions, and the speed was barely 20 knots with 15,750 horse power. During the fifth and sixth

hours the horse power indicated was 15,400 to 15,700—practically the same as in the first hour. The ship was running in water from 22 to 36 fathoms in depth, the revolutions were about 96½ and the speed was 21½ knots. In other words, with no change except depth of water, the speed rose 1⅓ knots, and shallowness involved an expenditure of power at 20 knots, which probably reached 3,000 horse power above what would suffice in deep water. Other examples of a similar kind might be given. They are scarcely necessary, however, to enforce the inference that in the trials of high-speed ships an appropriate depth of water is essential to a fair test of performance. Further, it is clear that a long straight run over a known distance is much to be preferred to short runs over a measured mile and intervening turns. Precautions must be taken, of course, to eliminate the effect of tides and currents, and in our trials this point receives full attention. If Mr. R. E. Froude succeeds, as I trust he will, in bringing his pressure-log experiments to a successful practical conclusion, another step will have been gained in the endeavor to secure the accurate and trustworthy results which must on all grounds be desired.

EFFECT OF DEPTH OF WATER ON SPEEDS OF SHIPS.

[Editorial in "The Engineer," London, April 22d, 1892.]

We shall scarcely say too much if we assert that no one appears to have any very accurate knowledge concerning the true speeds that any ship in her Majesty's navy can attain with a given horse power. It would appear, indeed that new discoveries are being made every day in connection with the subject, or that, at least, information previously possessed by a few individuals filters into the general stream of knowledge with extreme slowness. Mr. White's paper, for example, from which we have recently quoted at length, contains a statement which we have not the least hesitation in saying took us by surprise. We refer, of course, to the astonishing difference made in the speed pertaining to a given power by the depth of the water in which the ship moves. We have not the smallest reason to doubt the accuracy of the views he and the speakers who followed him

expressed. But important deductions follow. The first is that the facts ought to have been known at the Admiralty long ago. If they were, how has it come to pass that nothing whatever has been said about them before? It is clear that very great injustice may have been done to certain ships, and that, as a matter of fact, we must now always ascertain the depth of the water before we express an opinion concerning the merits or demerits of a vessel. We are strongly disposed to believe that the fact was not fully known at the Admiralty until recently. Of course, it has been understood for many years that the resistance of a fluid to the passage of a body through it is greatly augmented by want of volume in the fluid. Thus, for example, a tug-boat hauling a string of barges on a canal will make good way until she passes under a road bridge, where the towing path and canal are together spanned by one small arch. The water way is then so contracted that the boats do not clear the sides by more than a foot, and it is just as much as the tug can do to force the barges through this restricted passage. It was also pretty well known that in shallow water the speed of a ship fell off. But the notions entertained and beliefs held on the subject all contemplated cases in which the bottom was within a few feet of the keel. It now appears that the speed of a large steamer moving at a high velocity cannot be accurately obtained unless the water in which she moves is a couple of hundred feet deep or so. The question naturally arises, Why did not the late Mr. Froude, or his son, or some other careful experimenter and competent mathematician, tell the world all this long ago? If the facts stated by Mr. White are really in the nature of a discovery, it seems not improbable that all that has hitherto been taught concerning the resistance of ships will have to undergo modification.

When a ship like the *Teutonic* is at full speed, a mass of water equal to her own weight, say 14,000 tons, has to be got away from her in front every ship's length traversed, and will rush in to fill up the space that would otherwise be left void behind. As water is non-compressible, it is clear that it must be pushed bodily out of the way. It cannot go down, and in effect it fol-

lows the lines of least resistance, and is heaped up on each side very much as the mould-board of a plough heaps up the earth. The waves then partly roll over the normal level water, and lose their altitude in a way that has been fully investigated by mathematicians. Practically, there is a constant movement aft of the water at a rate commensurate with that of the advance of the hull forward. This action can be seen to perfection in a canal where the sides come close to the boat, as mentioned above. There is a sharp backward current set up between the sides and bottom of the canal and the boat, which is then virtually placed in the same condition as if she were advancing against a stream. The current under her is due, of course, to the head of water piled up in front, and no doubt there is a run of water aft under every ship, due to the same causes. But hitherto it has always been assumed that the run aft could not extend to any great depth. It is known that the apparent run aft along each side does not exceed in width a few feet at slow speeds, and a few yards at high velocities; and it must not be confounded with the "swell" which follows steamers and makes itself unpleasantly felt at considerable distances. That is not necessarily accompanied by any motion of translation, and represents the expenditure of but little power. Are we now to believe that a ship advancing through still water at twenty miles an hour or so sets up beneath her a current moving in the opposite direction some 50 feet or 100 feet deep, and that less space will not suffice to get rid of objectionable bottom friction? There are two classes of resistance to which a ship is exposed. The first and most important is skin friction, the second is that caused by eddies. For well formed ships it may be stated that Mr. Froude recognized no other resistances. The resistance due to form is simply eddy resistance under another name, and Rankine disposed of it and simplified matters by treating all the resistance as friction, adding what is known as "augmented surface" to compensate for the rejected eddies. A common proportion is 1.4. That is to say, the real wetted surface being 1 is dealt with as though it were 1.4, the fraction depending, however, for its amount on the form of the hull and its eddy-making powers. Now, it is clear

that the depth of the water can have no effect on the skin friction, consequently the augmented resistance due to shallowness must be purely a question of eddies; but how it is possible for a ship to set up eddies in water 50 feet or 100 feet below her keel is a point which we prefer to leave for investigation to, let us say, Mr. Froude.

In the discussion which followed Mr. White's paper, Mr. P. Watts confirmed the accuracy of Mr. White's views, and advanced an explanation which deserves careful consideration. He said that the experience of his firm, Messrs. Armstrong, Mitchell & Co., has been practically the same as the experience of the Admiralty with reference to the effect of depth of water on speed. His attention was very forcibly drawn to the importance of this matter in 1886, when a cruiser of about 19 knots speed which he had built obtained a greater speed after she had left his hands than had been obtained on the measured mile. She had been run on the measured mile near the mouth of the Tyne, just a little north of the mouth of the river, where, about half a mile out from the shore, the depth of water over the course varies from five to six fathoms at about half tide; and about a mile out from the shore this depth varies from thirty to forty fathoms. The ship had exceeded the guaranteed speed even before she left Elswick, but she had not reached the speed Mr. Watts considered she ought to have reached, and which she did subsequently reach at speed trials after she left England. It does not often happen that a ship is reported to have obtained a higher speed after she has left her builder's hands than could be obtained on the official trials, but it did happen in this case, and in looking for the reason for such an unusual circumstance it occurred to Mr. Watts that it might be due to the shallowness of the water over the course run; and in measured mile trials afterwards made this was shown to be the case. In 1888 he found that an 18½ knot cruiser of about 1,350 tons displacement lost about three-quarters of a knot when running in from six to seven fathoms. The *Piemonte* lost over a knot when running over the shallow course. These results agree pretty closely with the results given by Mr. White. With regard to the causes which produce

the retardation, Mr. Watts said: "It must be remembered that the depth of disturbance will vary very nearly with the square of the speed, and besides the frictional resistance due to the motion of the water over the ground, there will be additional wave-making resistance due to the fact that waves in shallow water can not travel as fast as waves in deep water."

In other words, this means that the ship drags water after her, and that when the water is not very deep the bottom offers a great resistance to the dragging. There is very little accurate information existing concerning the dragging of water by high speed steamers. DuBuat found that spheres vibrating in water increased the quantity of displaced fluid in the ratio of sixteen to one; but it is quite possible that at very high velocities the quantity dragged may be very small; its inertia overcoming the pull of the ship, the water slipping on itself, so to speak, and on the ship instead of advancing with her. But be this as it may, it is by no means clear that we have here any approach to a solution of the difficulty presented by the effect of want of great depth in the water. We are disposed to attach very much more importance to the fact that waves cannot travel as fast in shallow as in deep water. Thus the eddy resistance is augmented.

The uncertainty which exists regarding the true speeds of our war ships, that is to say, the velocity which they may be anticipated to attain at sea in service, does not depend solely on the depth of the water; there is another and most important condition, which has not yet been made public. It is simply that very many of our finest ships cannot carry firemen in sufficient numbers to work them at full speed. We provide forced draft, plenty of engine-power, and other things needful, and then we send these ships to sea short-handed. As a matter of fact, we have not half a dozen ships of large power in the Navy that could run at full speed, that is, about eighty per cent. of the full measured-mile power, for more than twenty-four hours. That could only be done by working the stokers in six-hour watches. The men could not hold out more than two watches each. At the end of the twenty-four hours they would be good

for very little, and the power of the engines would drop to probably fifty-five or sixty per cent. of the full power. This is the contingency on which we would have to reckon if ships had to be sent, say, to the Mediterranean in a hurry. It may be said, Why not ship more stokers? The answer is that they cannot be shipped because they cannot be berthed. There is no place to put them in. If more stokers are carried, then the complement of sailors, marines, and combatants in general, will have to be reduced. So much has to be packed into a modern man of war, that at last there is not room left for the men on whom she depends for utility.

THE SERVE BOILER TUBE.

[Editorial note in "London Engineering," April 1st, 1892.]

In order to determine the most suitable conditions for using the Serve tubes in boilers, Messrs. John Brown & Co., of Sheffield, have fitted up a complete testing plant, by means of which comparative figures can be obtained for the Serve tube and for the plain tube, under a wide range of working conditions. Thus experiments have been made with natural draft, with forced draft, and with induced draft, both when the air is supplied to the furnace cold and when it is previously heated, and much information of a valuable character has been gained. It has been found that for each variety of coal a certain degree of draft is required if Serve tubes are to be successfully used. Thus, when very smoky coal is used with low natural draft, the tubes choke up, and hence in future Messrs. Brown will not offer to supply tubes for such conditions of working. Such unfavorable conditions occur with small steamships having low funnels, but with high funnels, or with forced draft, no trouble is experienced even when smoky coal is burnt. When the draft is such that 30 pounds of coal are burnt per square foot of grate area, the tubes can be relied upon to keep clean. As the result of their experiments, Messrs. Brown recommend that with natural draft the height of a steamship's funnel should, if Serve tubes are used in the boiler, be 65 feet above the grates for Welsh coal, and 75 feet if smoky coal is used. Under such conditions the firm are

prepared to guarantee with the Serve tubes a minimum saving of 10 per cent. when cold air is supplied to the furnaces, and somewhat less when the air is previously heated. Messrs. Brown have also experimented with Howden's system of forced draft, and this inventor's spiral retarder has been fitted to the Serve tubes with great success, being fully as applicable to them as to plain tubes, and, with the combination of Howden's retarders and the Serve tubes, Messrs. Brown claim an advantage of at least 12½ per cent. over plain tubes similarly fitted, or of 20 per cent. over plain tubes alone. These results they state as the outcome of a long series of experiments, and they claim that they are borne out in practice. It would be of much interest if Messrs. Brown would publish full details of the results of their experiments.

TRIPLE SCREWS.

["Marine Engineer," London.]

The fitting of the triple screws in the new French armored cruiser *Dupuy de Lôme*, which was launched in October, 1890, and which is now being completed at Brest, and to the German protected cruiser *Kaiserin Augusta*, which was launched last January at Kiel, is an innovation, the results of which will be watched with interest by naval architects. Each of these vessels is upwards of 6,000 tons displacement. Hitherto triple screws have only been fitted to small craft, and only to very few of these. Indeed, so far as we know, the experiment has been confined to the Italian torpedo gun vessels, of the *Tripoli* class; and, although these boats were by no means failures, their three screws conferred upon them such slight advantages that it was decided to give the improved gun vessels of the same class two screws apiece only. In the case of such large ships as the *Dupuy de Lôme* and the *Kaiserin Augusta* the conditions are, of course, quite different, and it may therefore be that the anticipated advantages of triple screws will with them be fully secured. The *Dupuy de Lôme* is of 6,297 tons displacement, 374 ft. long, 52 ft. broad, and having a mean draught of 23 ft. 3 in. Her triple-expansion engines have a collective I.H.P. of 14,000, and will give a speed of 20 knots under forced

and 17.5 knots under natural draft. The *Kaiserin Augusta*, lately known as *Kreuzer H*, is of 6,052 tons displacement, and somewhat longer and narrower than the French ship. The engines will have a collective H.P. of 12,000. For ordinary cruising at speeds up to 12 knots it is intended to use the middle screw only. The two outside screws without the middle one, are anticipated to give a speed of 18 knots. The three combined should give a speed of 20 knots.

[It will be noticed that our "Pirates," *Cruisers 12* and *13*, are omitted from this list, which is the more remarkable, as they are larger than either of those given and are of vastly greater horse power. It may be remembered that a horse power of 20,000 and a speed of at least 21 knots are counted on for steady work, while it is expected that the maximum peformance will be 23,000 I.H.P. and 22 knots.—EDITOR.]

LARGE SAILING VESSELS.

In these days of economical machinery which secures a horse power for about a pound and a-half of coal, it would almost seem that there would be no demand for sailing vessels. Yet an examination of some recent English journals showed that a considerable number are building and in service, and most of them of large size. A single number of one of these journals recently issued mentions seven sailing ships launched within a year, each capable of carrying over 4,000 tons of cargo.

These vessels are, however, properly designated as "modern" sailing vessels, as steam is used for almost every purpose of power except propulsion, steam capstans, windlasses and winches being fitted, and in some cases distillers. The winches are used, not only for handling cargo, but also the gear for working the sails.

The dimensions of several of these vessels are about the same: length 326 feet, beam 42 to 43 feet, and depth 25 to 26 feet, carrying a dead weight of about 4,300 tons.

A notice has also appeared of a recent voyage of the *France*, the largest sailing vessel in the world, with a cargo of 6,000 tons of nitrate of soda from Iquique. Her dimensions are 375 feet by 50 feet by 34 feet depth.

SHIPS.

UNITED STATES.

Maine.—Hull and fittings generally about 75 per cent. completed. Work on the turrets well advanced. Joiner work is in an advanced stage and decks have been laid. The side armor has not been received. Work on the machinery is well advanced. All the main parts of machinery and boilers are now in place, and the work to be done is: fitting the valve gear in place; adjusting all journals and connections; making some sections of piping and completing erection of all; fitting smoke pipes on board; lagging boilers, piping, &c. It seems likely that, as far as the machinery is concerned, the vessel will be ready for dock trial about August 1st.

Texas.—Hull and fittings generally about 65 per cent. completed. Outside and protective deck plating nearly completed. The turrets are well advanced. The vessel can be launched in July if desired. The machinery, except the boilers and shafting, is practically complete in the shops. The condensers, outboard valves and propeller shafts have been placed on board. It may be remembered that the boilers were well advanced when the boiler shop was destroyed by fire and all the material condemned. It became necessary, therefore, to order new material and do all the work over again. Three of the boilers are assembled ready for riveting and the fourth is being drilled. Some of the riveting has been done on two.

New York.—Hull work is about 80 per cent. completed and the hull is ready to receive the boilers. These would have been in place on board but for the accident to the floating derrick. This will soon be repaired, when the boilers will at once be put on board. The engines and boilers have been completed in the shops, as well as most of the auxiliary machinery. The cylinders and framing of main engines, air and circulating pumps, condensers, and much of the auxiliary machinery are in place on

board. Present indications are that the vessel will be ready for trial in October or November.

Monterey.—The hull work is nearly done except fitting the armor for sides and barbettes. Fourteen of the side armor plates are in place and all but four have been shipped. Five plates for the barbette armor have reached San Francisco, and all of them have been shipped. The machinery is practically completed, the work remaining being such small items as completing the water service, fitting steam gauges, &c. The engines have been tried under steam, and the trial can now take place at almost any time.

Monadnock.—The new work needed to complete the vessel is about half done as far as the hull is concerned. The boilers and most of their fittings are complete and ready to go on board. All large castings about engines have been made, and most are complete. The engines have been erected in the shop, and the various parts are being fitted. The condensers are in position on board.

Indiana and *Massachusetts.*—The hulls are nearly completed to armor deck, including inner bottoms and bulkheads. About half the detailed drawings have been made and approved. Pattern work is well in hand. A number of valves, arms, bolts, &c., have been completed, and a great many of the smaller castings and forgings are being machined. A few of the large castings are being machined. Most of the boiler plate has been received, and some other boiler material. A beginning has been made on the main boilers, but the work is, as yet, not far advanced. The auxiliary boilers are nearly finished.

Oregon.—Framing completed to armor shelf. Stem, stern post and shaft struts cast. Fittings well in hand. The cylinders and liners of main engines have all been cast and partly machined, and the attachments and fittings are well advanced. The bed plates are partly machined. The engine framing is about three-fourths completed. Considerable work has been done on steel castings and the smaller steel forgings. The reversing gear is about three-fourths done. Work has also been pushed on many of the auxiliaries. None of the large steel forgings have

been received. The boiler plates and tubes are on hand and work has been begun.

Cruiser No. 6.—The hull framing is completed to the protective deck, and partly completed above. The outside, inner bottom and protective deck plating is nearly completed, and the work on hull fittings is progressing satisfactorily. The machinery is well advanced. The main engines are erected in the shop, and are complete except work on the shafting, a few of the connecting rods, some fittings, and the crank shafts. All the shafting is on hand, but none completed. The main boilers, condensers, all pumps, valves, blowers and turning engines are finished. One of the auxiliary boilers is finished and the other nearly so. The piping is well advanced.

Raleigh.—Was launched at the Norfolk Navy Yard, March 30, 1892. Work on hull and fittings rapidly approaching completion. The boilers, condensers, and many other parts of the machinery will be shipped from the New York Yard next month. (See under *Cincinnati* for state of machinery.)

Cincinnati.—The hull is about 70 per cent. completed, and preparations are making for launching, which can take place in July if desired. The machinery for this vessel and the *Raleigh* is all building at the New York Yard. All four sets of engines have been erected in the shop, and the crank shafts have been fitted in place. The reciprocating parts of two engines are complete, and of the other two about nine-tenths complete. All the shafting for both vessels is complete. The condensers and air pumps are complete, as is most of the piping about the engines. Work is well advanced on all the auxiliaries, and most of the valves and fittings about engines and boilers have been made. The boiler work is well in hand. Two of the small boilers are completed, and work on the others is in various stages of advancement. As a whole the boilers are about half done.

Detroit (*Cruiser No. 10*).—Hull work is almost completed. The machinery is well advanced. The boilers are finished and secured on board, and the uptakes, smoke-pipes and fittings are nearly done. The main engines and shafting are in place. Some of the auxiliary machinery is still in the shops. It is expected

that the machinery will be ready for trial about the middle of August.

Montgomery (*Cruiser No. 9*).—Work on the hull is being pushed. The machinery is nearly as far advanced as that of the *Detroit*. The present indications are that she can be tried in October.

Cruiser No. 11.—Hull work is well advanced, and the vessel is nearly ready for launching. The main engines and boilers have been completed in the shops, and work on the fittings is nearly complete. Some of the auxiliaries have not advanced very far, but will be ready before the machinery is erected on board.

Cruiser No. 12.—Framing is complete, protective deck laid and wooden berth deck being laid. All other hull work so far advanced that vessel will probably be launched next month. The main and auxiliary boilers have been completed, and the attachments and fittings are well advanced. The condensers are finished. The cylinders are practically finished, and the engine framing is about three-fourths done. Most of the valve gear and nearly all fittings, such as valves, &c., are done. Much of the auxiliary machinery is finished and the remainder is well advanced.

Cruiser No. 13.—About half the framing is completed to the protective deck, and the inner bottom plating is well advanced. Much of the material for the machinery has been received, and, in a general way, the work may be said to be about one-third advanced towards completion.

Machias (Gunboat No. 5).—The hull work is rapidly approaching completion. The machinery is well advanced, most of the larger parts being over nine-tenths completed. The boilers are on board and being secured in place. The shafting and other large forgings are about eight-tenths completed, and the piping is about half done. The vessel will probably be ready for trial in July.

Castine (Gunboat No. 6).—Was launched May 11th. Hull work is being pushed, and it is expected that the trials can take place in September. The machinery is in about the same state of advancement as that of the *Machias*, but the boilers are not. One is almost complete, and the other is assembled and being riveted.

Bancroft (Naval Academy Practice Vessel).—Was launched April 30, 1892. The machinery and boilers have been completed in the shops, and most of the auxiliaries have been placed in the ship. It is expected that the vessel will be ready for trial in July or August next.

Harbor Defence Ram.—Hull framing, outside plating and deck plating nearly completed. It is intended to launch the vessel the latter part of July. The H.P. and I.P. cylinders have been cast, as have the condensers, and the latter are about seven-tenths complete. The engine forgings, other than shafting, are about three-fourths complete. About one-fifth of the brass castings and about half the iron castings have been made. Much of the boiler material is on hand, but little work has yet been done on them.

ENGLAND.

Royal Sovereign.—"Engineering" of April 29, 1892, says: Last week the trials of H. M. S. *Royal Sovereign*, the largest war ship ever constructed, were carried out. At the time of the launch of this vessel, at the early part of last year, we gave a full description of her construction and machinery, and we need not therefore go into the matter very fully on the present occasion. It will be very convenient, however, if we repeat the outlines of the design. The *Royal Sovereign* is the first of the eight first-class battle ships provided for by the Hamilton programme. Four of these vessels have been constructed in the Royal dockyards and four by contract, Thomson's of Clydebank, Laird's of Birkenhead and Palmer's of Jarrow being the firms who succeeded in obtaining the orders for the contract-built vessels, Palmer's Company undertaking two of these enormous ships. They have, of course, all been designed by Mr. W. H. White, C. B., the director of naval construction. Seven of these ships have their guns mounted *en barbette*, whilst the eighth, the *Hood*, has turrets. The *Royal Sovereign*, it will be remembered, was constructed at Portsmouth. The length is 380 feet; breadth, 75 feet; and displacement, 14,150 tons.

At present we have to deal chiefly with the machinery, the

contractors for which are Humphrys, Tennant & Co., who are supplying the whole of the machinery for the four first-class battle ships of the Hamilton programme which were arranged to to be built in the dockyards. It may be mentioned that this firm has engined just one-half the number of battle ships in the Royal Navy, taking the list of thirty-two ships as given in Lord Brassey's paper read before the Institution of Naval Architects last year, out of which sixteen have been supplied by machinery from Messrs. Humphrys' shops. In our issue of February 27, 1891, we gave pretty full details of the machinery, and will, therefore, now content ourselves with stating some of the chief features. The *Royal Sovereign* being, like all ships of the present day, a twin-screw vessel, has two sets of main engines. These are of the vertical three-stage compound type, with three cranks. They were designed to indicate 9,000 horse power with natural draft, and 13,000 indicated horse power with forced draft. The cylinders are respectively 40 inches, 59 inches and 88 inches in diameter, and the stroke is 4 feet 3 inches. The cylinders are placed in the order of high, intermediate and low. All have ordinary slide valves worked by eccentrics, with link motion with the usual character, the link being a single solid bar. The high and intermediate valves face each other, and the low-pressure is inside. The frame work consists of turned pillars in front and a casting at the back, the crosshead slipper guides being formed in the latter. The condensers, one to each engine, have 14,000 square feet of cooling surface in the two. They are placed immediately at the back of the low-pressure cylinders, and occupy very little floor space, being carried to a good height. The engine rooms are in fact spacious and comfortable throughout, and afford a pleasant contrast to the cramped arrangement of some of the smaller vessels of the navy. There is also a condenser for auxiliary work in each engine room, the combined surface being 1,800 square feet. In these engines the air pumps are worked direct from the low-pressure pistons, each cylinder bottom having a stuffing box for the pump rod to pass through. The air pump is mounted inside the main standard. This makes a very snug job, but the attachment of the rod to the piston has, natu-

rally, to be some distance from the center of the latter. This, however, does not affect the working to any appreciable extent, and no special provision has to be made to meet the case. The air pumps are 18 inches in diameter. The propellers are four-bladed, 17 feet in diameter and 18 feet mean pitch. They are of gun metal.

The boilers are eight in number, single-ended, and placed back to back, the stokeholds thus running fore-and-aft. There is no auxiliary boiler. The diameter of each boiler is 15 feet 2 inches, and the length is 9 feet 4 inches. Each boiler has four furnaces and each pair of furnaces has one combustion chamber, so that there are two combustion chambers in each boiler. The grate area is 700 feet and the heating surface 19,560 feet. The fans for forced draft are eight in number and are driven by a Brotherhood engine. The steering engine is by Muir & Caldwell, of Glasgow, and works the tiller by a double yoke and chain. In this compartment are two capstan engines by Harfield. The hydraulic machinery for working the gun platforms in the barbettes is placed behind the armor of the barbette, the hydraulic pumping engine being well below water. The hydraulic engines are of the three-cylinder type, the cylinders being placed horizontally on trunnions. They work to 1,000 lbs. pressure. This machinery is by Armstrong, Mitchell & Co. There is a strong brake to hold the gun platform steady when it is not being turned. This brake is automatically put into action by means of the pressure when the engines are not at work, and is released by a strong spiral spring. This machinery is actuated from the gun platform of the barbette. There is also a small hydraulic gear for working the platform in harbor, &c., in addition to hand gear. The engines for supplying the power for working the barbette are each 600-horse power indicated. There are duplicate pumping engines in case of damage; that is, each set of engines is capable of supplying power for working either or both barbettes.

In other compartments there are the air-compressing machinery, the electric light machinery and the ventilating machinery, the latter consisting of twelve fans, each with its separate

engine. There is a very snug little engineer's workshop, containing two lathes, a drilling machine, shaping machine, punching and shearing machine, and sundry other tools. This is served by a separate engine. There are other auxiliary engines, the total number, we believe, being 78. The total weight of all machinery, including water in boilers and condensers, was estimated at 1,110 tons. We are not aware whether the actual figures have come out in accordance with this estimate, but no doubt they do not differ materially. The following details of estimated weight may be of interest:

	Tons.
Engine and shafting in engine room and spare gear, auxiliary machinery &c., ...	379
Water in condensers, pipes, &c., ...	23
Screw propellers, stern fittings, &c., shafting not in engine room, ...	123
Boilers, funnels, casings, pipes, &c., ...	457
Water in boilers, 7 in. above highest heating surface, ...	128
Total weight, ...	1,110

A notable feature in the design of this ship is a wide passage amidships running fore-and-aft for the greater part of the length of the vessel over the magazines and between the engine rooms. This, of course is below the water line, and it contains the fire mains, the electric light wires, voice pipes, &c.

The *Royal Sovereign* had been taken out to the anchorage off Spithead on Monday of last week, Easter Monday, and on Tuesday, the 19th inst., the natural draft trial was carried out. The weather was fine and the sea smooth, there being a light wind from the southwest. The vessel got under way about 7 o'clock, and soon after 8 the trial commenced. A course of 9½ nautical miles had been laid down on the chart, the points being the Owners' Lightship and the Bullock Patch Buoy. Over this course the vessel was run four times, and the speed was 16.31 knots. The mean collective indicated horse power was 9,444. Four runs were afterwards made on the measured mile, the mean of which showed a speed of 16.77 knots, the horse power

being 9,760 indicated, so presumably there was somewhat harder blowing on the mile, though of this we have no information. The following were the particulars registered: Boiler pressure, 150.3 lbs.; vacuum (starboard and port), 28.3; revolutions, starboard engines, 97.3 per minute; port engines, 96.3 per minute; indicated horse power, starboard engines, 4,922, and for port engines, 4,722; total collective and indicated horse power, 9,644. This was a very satisfactory result, as the power developed was 644 units in excess of the contract. In old days, before the Evil one invented forced draft, the contractors might have gone home happy, and Admiralty officials have slept that night in peace.

The full-power trial took place on the day but one following. The difference between getting 9,000 to 10,000 indicated horse power out of machinery, and pressing the same engines and boilers until they gave out 13,000 indicated horse power is very great. The latter was the task set before the contractors on Thursday (21st April). Overnight there had been a stiff breeze with driving rain squalls, and there was every chance of a south-westerly gale for the next day. Fortunately the wind died down towards the morning, and when the shore party started from the dockyard the weather was as bright as could be wished. As the tide was low, and there would be little water on the Stokes Bay mile, it was determined to run the four hours' trial by steaming right away to the eastward and then back. This would have the advantage of giving the ship deeper water and a clearer course than could be got if the vessel had to go inside the Wight. The time was taken on passing the Owners' Lightship, and Beachy Head was reached before a turn was made. The wind, which was light, was right astern on the run out, and, as it remained steady throughout the trial, the return run was made dead to windward. The wind of the previous night had set up a moderate sea, but the waves were easy and hardly perceptible on the steady platform of the enormous battle-ship; although one or two vessels met on the course indicated that there was a fair amount of motion for less favored craft. The draught of the vessel was 26 feet 8 inches forward and 28 feet aft.

The following are the particulars of the trial, and refer to the first three hours of the run: The boiler pressure was 155 lbs. The vacuum in the starboard condenser was 28 inches and in the port condenser 27.54 inches. The revolutions of the starboard engines were 106.6 and of the port engines 105.9. The indicated horse power was as follows:

	Starboard.	Port.
High-pressure cylinder, . .	1,645	1,991
Intermediate cylinder, . . .	2,303	2,188
Low-pressure cylinder, . . .	2,676	2,509
	6,624	6,688

This gives a collective mean indicated horse power of 13,312, or 312 indicated horse power above the contract. The mean pressures in starboard engine cylinders were as follows: High, 47.66 lbs.; intermediate, 30.65 lbs.; and low, 16.11 lbs. Port engines, high, 58.03 lbs.; intermediate, 29.31 lbs.; low, 15 11 lbs. The mean air pressure for draft during the three hours was 1.6 inches on the water gauge. The speed of the vessel was 18.1 knots.

The above figures are very satisfactory so far as they go, but it will be noticed that they refer to a three-hours' trial only, whilst the regulation time for a full-power trial is four hours. Unfortunately, during the fourth hour the tube ends commenced to leak, and, although this was not to a sufficient extent to stop the trial, it was very fairly decided to throw out the last hour. It may be here stated that the leakage turned out on examination to be less serious than was originally supposed, and the ship was able to go on her gunnery trials, which were brought to a satisfactory conclusion the next day, with all furnaces alight.

Spartan.—This vessel is one of the sheathed second-class cruisers built under the Naval Defence Act of 1889. Similar ships have been described in recent numbers of the JOURNAL, but the principal dimensions are here recapitulated: Length, 300 feet; beam, 43 feet 8 inches; mean draught, 16 feet 7 inches; displacement, 3,600 tons.

The engines are twin-screw, vertical and triple-expansion, with

cylinders 33½, 49 and 74 inches diameter by 39 inches stroke. There are three double-ended and two single-ended boilers, with an aggregate heating surface of 16,000 square feet.

The natural-draft trial took place off Plymouth early in March, and a speed of 19.7 knots was obtained for 7,799 I.H.P., the conditions being favorable. The air pressure in fire rooms was about ⅛ inch of water.

The forced-draft trial took place a few days later, but under unfavorable circumstances of weather, a wind of force 6 to 7 by the Beaufort scale blowing. Although when steaming head to wind, the spray was thrown as high as the funnel, the mean speed for four hours was 20.44. The following are the machinery data: Steam at boilers, 148 lbs.; air pressure in fire rooms, 0.92 inch; vacuum, 28.6 starboard and 27.1 port; revolutions, 141.7 starboard, 141.8 port; mean pressures in cylinders: starboard H.P., 55.1; I.P., 30; L.P., 13.3; port H.P., 59.2; I. P., 31.6; L.P., 12.8. Indicated horse power: starboard H.P., 1,357; I.P., 1,583; L.P., 1,604; port H.P., 1,459; I.P., 1,666; L.P., 1,536—total, starboard, 4,544; port, 4,661; both engines, 9,205.

Torpedo Gunboats.—The flotilla of torpedo gunboats is to be further strengthened by the addition of two new vessels of a somewhat larger type than the *Halcyon*, recently commenced at Devonport. The new vessels, which will be constructed under the Naval Defence Vote of 1889, are to be named the *Dryad* and *Hazard*, and will be provided with engines of 3,500 H.P., the resulting speed being estimated at about 19.5 knots. If this speed is realized it will enable them to outstrip any of the *Sharpshooter* class, and grapple with most of the first-class torpedo boats likely to be met with in a future engagemeut. The utility of the torpedo gunboat, or torpedo-boat catcher, as it is more popularly termed, is recognized by all authorities on naval matters, but the limit to its size is a question upon which opinion is in no way confined. The French were the first to adopt this particular type of vessel by the construction of the *Bombe* of 340 tons displacement, which was launched in 1885. Two years later the *Rattlesnake*, *Grasshopper*, *Gadfly*, and *Spider*, each of 450 tons and 3,000 H.P., were added to the British Navy.

These vessels, which were more or less successful, were intended to steam at 19 knots, and cost about $175,000 each, but with a desire to combine high speed with better sea-going qualities, the *Sharpshooter* class was subsequently designed of 735 tons, to realize 21 knots with 4,500 H.P. In all, thirteen of this type have been built during the past three years, but not one of them has ever approached their designed speed. The best results were obtained with the *Gleaner*, built and engined at Sheerness dockyard. On her recent forced-draft trial a mean speed of 20.1 knots was recorded over a three-hours' run, the collective H.P. being 3,631. The pressure of steam was 147 lbs. per square inch, revolutions, 249.6 per minute, and the vacuum 28.5 inches.

The cause of the failure of the *Sharpshooters* is due to the weakness of the hull in comparison to the power of the engines. Consequently, in the third type of torpedo gunboats at present under construction, the displacement has been increased to 810 tons, and the I.H.P. of the engines reduced from 4,500 to 3,500. Of this latter class there are four building at Sheerness and two at Devonport, none of which however are in a very forward state, so that it will be some time before a comparison can be instituted between them and their predecessors with regard to their speed qualities.

Thus in five years the English torpedo gunboats have increased in displacement from 450 tons to 810 tons, or about 80 per cent. Perhaps the limit will be reached in the *Dryad* and *Hazard;* if not, the distinctive character of the torpedo gunboat will be lost in that of the cruiser.

The Torpedo Gun-vessel Speedy, which is being built for the English Navy by Messrs. Thornycroft, of Chiswick, is expected to be one of the fastest vessels of her class in that service. A member of the firm has stated that he anticipates that she will attain a speed of between 21 and 22 knots. In connection with this statement, it may be worth while to add a list of the fastest torpedo boats and torpedo gun vessels of less than 1,000 tons displacement which have hitherto been ordered by, or completed for, the leading naval powers. These are: Great Britain—*Speedy*,

21.5 knots; *Torpedo Boat No. 80*, 23 knots. France—*d'Iberville*, 21.5 knots; torpedo boats *Coureur*, *Veloce* and *Grondeur*, 23.5 knots. Germany—*Division Boats Nos. 5* and *6*, 22 knots; *Torpedo Boats Nos. 65* to *74*, 24 knots; *Nos. 76* to *80*, 25 knots; *Nos. 75* and *81* to *96*, 26 knots. Italy—*Tripoli*, 23 knots; torpedo boats of *Aquila* class, 25 knots. Russia—boats of *Adler* class, 26.5 knots. Austria—boats of *Komet* and *Trabant* classes, 20.5 knots; torpedo boats of *Falke* class, 22.4 knots. United States—*Cushing*, 22.5 knots. Argentine Republic—six 130 feet Yarrow boats, 22.5 knots. Chili—*Lynch* and *Condell*, 21 knots; torpedo boats of *Glaura* class, 22 knots. China—torpedo boat (by Schichau), 24 knots. Denmark—two torpedo boats, 22.1 knots. Spain—*Destructor*, 21 knots; torpedo boats of *Rayo* class, 24 and 25 knots.

Progressive-Speed Trials.—The accompanying interesting table was given in Mr. W. H. White's paper before the Institution of Naval Architects, of which another extract is given elsewhere in this number:

RESULTS OF PROGRESSIVE SPEED TRIALS IN TYPICAL VESSELS.

	Torpedo Boat.	Torpedo Gunboat, *Sharpshooter* Class.	*Medusa.* Third Class Cruiser.	*Terpsichore.* Second Class Cruiser.	*Edgar.* First Class Cruiser.	*Blenheim.* First Class Cruiser.	Atlantic Passenger Steamer.
Length (in feet)	135	230	265	300	360	375	535
Breadth (in feet)	14	27	41	43	60	65	63
Draught (mean) on trial: feet: inches	5-1	8-3	16-6	16-2	23-9	25-9	21-3
Displacement (tons) on trial	103	735	2,800	3,330	7,390	9,100	11,550
Indicated H.P. 10 knots	110	450	700	800	1,000	1,500	2,000
" " 14 "	260	1,100	2,100	2,400	3,000	4,000	4,600
" " 18 "	870	2,500	6,400	6,000	7,500	9,000	10,000
" " 20 "	1,130	3,500	10,000	9,000	11,000	12,500	14,500

Aurora.—The engines of the first-class armor clad *Aurora* have again developed serious defects, and are being taken to pieces at the Devonport dockyard, that the necessary repairs may be commenced without delay. Last year new pistons were supplied to the *Aurora* by Messrs. Armstrong, Mitchell & Co., Newcastle-on-Tyne, to replace those originally fitted by the mak-

ers of the machinery, which had on service proved defective. The new pistons were much stronger than the old ones, and it was consequently anticipated at the time that no further trouble would be experienced. On service, however, endurance was a quality found wanting, and under ordinary circumstances of cruising more or less trouble was experienced, throngh the continual bending of the piston rods. But the climax was reached a few weeks ago, when the Admiralty directed that the *Aurora* should undergo a four-hours' natural draft trial at full power. It was then found that the pistons and piston rods had developed such serious imperfections that the trial was abandoned. As a consequence the vessel was ordered home, and the *Narcissus*, a sister ship, is to take her place in the Channel squadron. She was completed in 1889, at a cost of about $1,400,000, including machinery, and was commissioned at Devonport, on 18th July, 1890. The *Aurora* was built at Pembroke dockyard, and supplied with machinery by Messrs. J. & G. Thomson, Clydebank.

Sybille,—one of the second-class cruisers known as the *Apollo* type, built under the Naval Defence Act of 1889, completed her machinery trials off Plymouth in a highly satisfactory manner on 31st March. The *Sybille*, which has been built by Messrs. Robert Stephenson & Co., Limited, Hebburn-on-Tyne, is 300 feet long by 43 feet beam by 16 feet 6 inches draught, having a displacement of 3,427 tons. Her machinery, which has been constructed by Hawthorn, Leslie & Co., consists of two sets of triple-expansion engines having cylinders 33½ inches, 49 inches, and 74 inches, by 39 inches stroke, to which steam is supplied by three double-ended and two single-ended cylindrical boilers working at a pressure of 155 lbs. per square inch. The power to be developed by these engines and boilers under the contract is 7,000 mean I.H.P. upon an eight hours' trial, with an air pressure not exceeding ½ inch of water column, and 9,000 I.H.P. on a four-hours' forced-draft trial, the air pressure being limited to 1 inch. The eight-hours' trial was run on 24th March, the contract H.P. being exceeded by 632 with the very low air-pressure of .106 inches. On the forced-draft trial run on 31st March, the low air pressure was again a noticeable feature, the

contract power being exceeded by 496, with only .48 inches air pressure. The engines ran very steadily and satisfactorily throughout both trials, there being an entire absence of either heating or vribration. The following are the details of the trial results, these means being obtained by hourly records upon the eight-hours' trial, and half-hourly records upon the forced-draft trial:

	Eight-Hours' Trial.	Four-Hours' Trial.
Mean steam, ...	146	149
" air-pressure . .	.106	.48
" vacuum, . . .	28¾ in.	28 in.
" revolutions . .	135.2	145
" I.H.P.	7,632	9,496

The *Sybille* has the first of five similar sets of machinery which Messrs. Hawthorn, Leslie & Co. are at present constructing for the Admiralty.

Gleaner.—An official examination has been ordered of the boilers of the *Gleaner*, at Portsmouth. The vessel is one of the eighteen first-class gunboats provided for under the Naval Defence Act, and early in April she was sent round from Sheerness, where she was built, for the trial of propellers of various patterns on the measured mile. On Thursday, April 7th, the *Gleaner* went out of harbor for the trial of a three-bladed Mangin screw, the peculiarity of which is that each blade has a second blade placed immediately behind it on the same boss. Before the runs at different rates of speed had been completed the water in two of the boilers was seen to fall, and, with the object of ascertaining the cause, the Staff Engineer in charge of the trial placed his ear to the feed valve to count the beats of the pump. Immediately after he had left the spot the casing of the check valve burst and the stokehold was inundated with steam and water. The fires in the furnaces were promptly extinguished without anyone being injured, and the vessel returned into harbor with two boilers alight. An examination of the boilers of the *Gleaner* at Portsmouth has convinced the experts that the bursting of the box of the check valve was due to the defective arrangement of the interior feed pipes. This is to be altered at once.

Blenheim.—This new first-class cruiser, a sister ship to the *Blake*, underwent a full power trial of her engines on February 9th, off Plymouth, with forced draft. She returned to the sound, and, after signalling to the commander-in-chief that the results were unsatisfactory, the *Blenheim* left immediately for Portsmouth, where, it is understood, certain alterations will be made. The boilers of the *Blenheim* do not resemble in some particulars those of the *Blake*, and it was hoped that she would have developed the contract 20,000 H.P. Her trials have all, hitherto, been unsatisfactory. Their want of success was attributed mainly to the fact of the trials having been made in shallow water, and for that reason the *Blenheim* was sent to Plymouth for her forced-draft test. It would seem that the authorities have overestimated the beneficial effects of deep water, and the fault will probably prove to be want of space in the fire-grates and combustion chambers. The *Blenheim* was put through a series of progressive steam trials at Portsmouth on February 16th, with the object of determining the relations of power to the performance of the ship under various degrees of speed. The results proved very satisfactory as regards the coefficients between vessels and engines. With 39 revolutions and 1,028 H.P., a mean speed of 8.334 knots was obtained; 50 revolutions and 2,079 horses gave 11 knots; 66 revolutions and 4,877 horses gave 14.64 knots; and 84 revolutions and 9,758 horses gave 18 knots. After testing her anchor and steering gear she proceeded to Chatham to prepare for her forced-draft trials.

Ramillies.—At a time when so much is being written on the subject of the relationship of the government to private manufacturers, and of the necessity of these latter being encouraged to perfect their means of producing munitions of war, the floating on Tuesday from the yard on the Clyde of Messrs. J. & G. Thomson, Limited, of H. M. S. *Ramillies*, the largest battle ship yet launched from a private establishment in the United Kingdom, and indeed in the world, and costing $4,100,000, is worthy of more than a passing reference. The contention for a closer bond between the army and navy departments and the private establishments in the Kingdom is based on the necessity of the

government having at their disposal the most extensive resources possible at a time when war is imminent or even probable, and although that would scarcely be a time to lay down battle ships, it is desirable to have yards equipped for the building of battle ships, on the principle that a works capable of keeping pace with the Royal dockyards in the building of large vessels may do similarly well with small craft. Besides, the building of ships of war requires quite an education on the part of the workmen as well as of superintendents. In the building of a cargo steamer or "tramp," "the rule of thumb" is a useful factor, but when a war ship is in course of construction drawings must be made almost for every detail. In the case of the *Ramillies* there have been 5,000 plans in use, and they were constantly in requisition. The men in the Clydebank yard of the Messrs. Thomson, Limited, are now quite used to such important work. Indeed for several years past they have seldom been without a war ship or 20-knot steamer, and in the past two years they have had something like a million and a third sterling of work from the Admiralty. Besides, the Messrs. Thomson have designed and built several remarkably successful craft for foreign countries, including Spain, Russia and Japan.

The Admiralty had, therefore, confidence in placing an order for a battle ship of over 14,000 tons with the firm in November, 1889, and the work has been quickly done. It is not necessary to enter at any length into the design of the ship, since she belongs to a class of which four have been launched from government yards, the last, the *Repulse*, having been floated on Saturday last from Pembroke, while three others are building in private yards and will be launched in the course of the year, one at Birkenhead and two at Messrs. Palmer's, on the Tyne. Although the *Repulse* was on Saturday launched from a slip, battle ships are built in dockyards, as a rule, in docks, and the floating out process is a commonplace affair, exercising all the ingenuity of the journalist to invest it with an importance befitting the occasion. In private yards the vessels are built on land, and at Clydebank the *Ramillies* was constructed on the spot where the famous Atlantic liners, *City of Paris* and *City of New York*, were

created. The process of launching usually has all the excitement of a journey down a toboggan slide. In the first place, a sure foundation on which to build the ship had to be made. The ground of the building site was fortunately very solid, and the only precaution necessary was to cover the site with logs of wood, while piles were driven to support the end of the launching ways. Not everyone knows that to be safe the grade of a toboggan slide must suit the clear run on the level ground at the foot. So with the launching of a ship, and as the Clyde opposite the Messrs. Thomson's yard is narrow, they determined to give the *Ramillies* a grade of $\frac{5}{8}$th of an inch to the foot.

The extreme coldness of the weather suggested the probability that the lubricants on the ways might not allow the vessel to have the usual speed, and the result certainly gave the launch interest. The dog shores were knocked away and the ship left free to move, but there was no perceptible movement. The hydraulic ram, usually placed under the keel at the bow of all ships when being launched, was put in operation, and after five or six minutes' work the vessel began to move, and the Duchess of Abercorn formally named the ship. For a long time the rate of progress of the huge mass of 7,000 tons weight was about one inch per minute, a rate of movement quite in keeping with the dignity even of a great British battle ship. In an hour she had moved several feet. But nineteenth century notions seem to have asserted themselves on the part of the workmen, who were not quite satisfied with this "masterly inactivity" in an age when all is hurry, so these unsympathetic workmen tried to push her off by main force, but, of course, in vain. As a last resource, tugs in the river were attached to draw the ship off. Then, and not until then, did the rate of progress quicken, but it was still extraordinarily slow. It continued to grow, however, and the movement became one which could be followed by the eye. Gradually she gained way, and at last, as if to show that her power and vitality had been merely dormant, she moved at a good pace into the water, dragging the anchors, plates, &c., buried in the earth, for something approaching 70 yards. She had been 1 hour and 26 minutes in continuous motion, traversing a dis-

tance of about 460 feet, and an hour later she was safely berthed in the company's dock.

The keel of the *Ramillies* was laid in August, 1890, so that she has only taken 19 months to build, and when we remember that great credit was and is still taken for the building of the sister ship, *Royal Sovereign*, in the Portsmouth royal yard, with all its resources, in 17 months, and that the Devonport yard took 22 months to the *Empress of India*, and the Pembroke yard 34 months to build the *Repulse*, launched on Saturday last, Messrs. Thomson are to be congratulated on their performance. In the initial stages 40 tons of steel were built into the ship each day, and now there are a million and three-quarter rivets holding the structure together. These weigh 300 tons. The plates, previous to their being taken in hand for working, had to stand for a few hours in a liquid consisting of nineteen parts of water and one part of hydrochloric acid. When the plates were removed from the dilute acid both the surfaces were well brushed by brushes worked by machinery, and washed to remove any scale which might still adhere to them. They were then thoroughly washed with fresh water by the aid of a hose; then placed on the edge to dry. This process removed all the black oxide or scale which adheres to the plates, and has the effect of corroding them when placed in communication with sea water. The ship was ready for the armor plating in August, but the plates were not forthcoming. Owing to the simultaneous building of eight battle ships under the Naval Defence Act, steel manufacturers had their resources severely taxed; otherwise the *Ramillies* would have been launched some time ago. The armor extends for 250 feet along each broadside of the ship, and at each end the two sides are connected by a transverse armor belt. The general arrangement of the protective deck, &c., was described and illustrated in the previous articles already referred to. The belt is 18 inches thick, and required special machinery to work it. The drilling of the holes, 5½ inches in diameter, for the bolts, was done by electric power with specially-devised machinery, the perforation of the hole in the plate and in the teak backing being one operation. So complete were the arrangements that 3½

days served for the preparing and fixing of each armor plate weighing 30 tons. The plates are of compound steel, the outer face being of hard steel, while the inside portion is much softer and more ductile, and prevents the cracking of the hard steel face by the impact of shot. As it is important to avoid making any holes in the hard steel face, the plates are secured by bolts 5½ inches in diameter, having a screw thread in each end. A hole is made in the softer steel in the inside of the armor plate, and when the plate is put on the ship's side the bolt is passed through from the inside of the ship and is screwed into the hole made in the inner part of the armor plate. A long washer is passed over the inside end of the bolt and rests upon the inside of the skin of the ship, and inside of all a large nut is "hove up" on the end of the bolt, which completes the security of the plate.

The 1-inch steel skin of the ship above the armor belt is covered with 4-inch steel armor, which protects the quick-firing gun deck. The 67-ton guns are mounted *en barbette*, two forward and two aft. The armor in each barbette weighs 643 tons without the backing. The barbette was chosen in preference to the turret because it raised the guns higher and admitted of increased freeboard—it is 18 feet against 10 feet 3 inches in the *Admirals*. This, in the interest of the men, is a much needed improvement. The tops of the barbettes project 2 feet 9 inches above the upper deck. The axes of the 67-ton guns are only 4 feet 6 inches above the deck.

There are seventy-eight separate engines in the ship. The main propelling engines consist of two sets of engines of the triple-compound type. They are in separate compartments with the powder magazine between, so that it will be very difficult for a shot to pass through to the explosives, as in addition to the armor it will require to penetrate through coal bunkers and the engine compartment with its many obstructions. It is not necessary now to enter into details as to the engines, as we hope at a later date to illustrate them. Steel and naval brass have been largely used to reduce the weight, and it is expected that the maximum power of 13,000 indicated horse power will be got with a creditably small ratio of weight. Almost everything in

the ship is done by machinery, and the engines incidental to the propelling machinery are all independent. Everything, too, is in duplicate, so that should an engine get out of order another engine is available. The steam is supplied by eight single-ended return-tube boilers, each with four furnaces 3 feet 6 inches in diameter. For the purpose of shutting off each combustion chamber from the others, and also for regulating the draft, separate dampers are fitted in the passage from each furnace through the smokebox, and gearing is arranged to work these dampers from the stokehold floor. Each pair of boilers is in a separate water-tight compartment, with independent coal supply. For some time both sets of main engines have been completely fitted up to the smallest detail in Messrs. Thomson's works, with the condensers and all connections and shafts in position complete. In the boiler shop, too, the eight boilers are all arranged in position, with smokeboxes, uptakes, and all boiler mountings, furnace fittings and firebars, and the two funnels, each 8 feet 6 inches external diameter and 90 feet high from the furnace level, lying ready for putting on board, so that when the ship gets under the 120-ton sheerlegs at the company's docks these will quickly be put on board, and the vessel will doubtless soon attain her guaranteed speed of 17½ knots.—"Engineering," March 4, 1892.

FRANCE.

The French Shipbuilding Programme for 1892.—It is said that during 1892 twenty-two vessels will be laid down for the French Navy, including two line-of battle ships; one first class cruiser; one third-class cruiser; two first-class cruisers for foreign service; one vessel similar to the English *Vulcan* to serve as a torpedo depot ship; one torpedo gunboat to be named the *Cassinê*; three first-class sea-going torpedo boats; ten second-class torpedo boats; and one sea-going torpedo boat with exceptionally high speed.

Of the two line-of-battle ships, one will be constructed at Lorient and the other at Saint Nazaire. The former is expected to be advanced only by a half per cent. of its construction at the

end of the year, the latter is expected to be advanced seven per cent. The plans are not yet fully decided on, but it is known that the displacement will closely approach to 12,000 tons, with which it is hoped that a speed of 18 knots per hour under forced draft may be obtained from each of the two ships.

The first-class cruiser intended for service with a fleet will be constructed by private builders, probably by the Forges et Chantiers de la Méditerranée at La Seyne. It will be of the *Charner* type modified; its displacement will be about 5,000; the speed demanded, 19 knots per hour under forced draft; this vessel should be advanced by nine per cent. of her construction by the end of December.

The third-class cruiser, also destined for fleet service, will also be built by a private firm. It is of the modified *Surcouf* type, having a displacement of 2,200 tons, and a maximum speed of twenty knots. This cruiser is to be pushed forward eleven per cent. during the present year.

Two cruisers of the first class, for foreign service, will also be commenced; one at Toulon, which should be advanced six per cent. at the end of the year, and the other, in a private yard, which should be advanced by five per cent. of its total construction at that date. These cruisers are destined to replace the vessels of the *Laperouse* and *Villars* types, and will have a displacement of nearly 3,900 tons, and a speed of 18 knots with natural and 19 knots with forced draft. Their armament will consist of four 16 centimeter guns, and ten of 10-centimeters, all being of the breech-loading, quick-firing type. It is intended that these vessels shall carry sufficient coal to enable them, at a speed of 10 knots per hour, to keep the sea for a distance of 5,500 nautical miles.

The torpedo depot ship, the *Foudre*, will be commenced without further delay, and will be constructed by a private firm. It should, by January, 1st, 1893, be advanced 15 per cent.

The *Cassiné*, torpedo gunboat, is of the same type as the *d'Iberville*, which has just been laid down, and will likewise be constructed in a private shipyard. Some of the particulars of this vessel are as follows: Displacement, 925 tons; I.H.P., 5,000;

maximum speed, 21.5 knots per hour; armament, five torpedo-launching tubes, one quick-firing gun of 10 centimeters, three quick-firing guns of 65 millimeters, and four of 37 millimeters. Fourteen per cent. of this vessel should be constructed at the end of 1892.

All the torpedo boats are to be given for construction to private yards. The three sea-going boats should be advanced by 20 per cent. of their total construction during the year; the others are to be advanced as quickly as possible, and every effort is to be made to give them the highest speed attainable.

Cruisers of the French Mediterranean Squadron.—At a time when so much is being said about the failures of ships recently built for the English Navy, it is interesting to note that other countries are troubled in this way, and that their engineers are struggling under the same or similar difficulties and are on the whole no more successful than those of England. Of late some of the English cruisers have been most severely criticised and condemned, perhaps with reason; but the French have been no more successful with this class of ship, although the failures and difficulties incurred are not made so widely known as in England, great care being taken by the Government authorities to keep such matters as far as possible secret. As examples of this may be taken the following cruisers, which form nearly the whole of the unarmored portion of the French Mediterranean fleet, either in service with the active fleet or on the reserve.

First, the *Tage*, a first-class cruiser of 7,045 tons displacement, launched at Saint Nazaire by the Société des Forges et Chantiers de la Loire in October, 1886, being the largest cruiser of the fleet, and which on her trials gave a speed of slightly over 19 knots per hour under forced draft. This ship rendered excellent service in the naval manœuvres of the Mediterranean fleet carried out last summer, and received a great deal of credit for the same, but on entering Toulon harbor with the fleet, the vessel was at once put on the reserve, having given great trouble at the latter part of the manœuvres, owing to the leaky state of the boiler tubes, and to the fact of the liners of the cylinders of her compound horizontal engines having been greatly worn.

The ship was shortly after put on the third class of the reserve, and is now in the arsenal having both the boiler tubes and the cylinder liners renewed. This fact becomes worse when it is remembered that during the manœuvres the officers of the ships taking part had the strictest orders not to force the ships to their utmost speed at any time.

Next comes the *Cécille*, almost a sister ship to the *Tage*, but smaller, with a tonnage of 5,766, built by the Société des Forges et Chantiers de la Méditerranée at La Seyne, and launched in 1888. This vessel gave the greatest trouble in obtaining the specified speed of 19 knots per hour, trials being made at intervals during eighteen months before this speed was obtained. During this time many of the most important moving parts, and the various bearings of her vertical engines were changed, new pieces of different design being substituted. The *Cécille* was not run hard during the manœuvres and is still serving with the active fleet, of which she is undoubtedly the best and most useful cruiser. It is only just to add that on her final trials the *Cécille* gave most satisfactory results, giving a maximum speed of 19.2 knots per hour.

The *Jean-Bart*, lately sent from Rochefort, where she was built, to join the Mediterranean fleet, is at present on the reserve, the trials for obtaining the expected speed of 19 knots per hour not having yet been fully satisfactory. It is probable that the trials of this vessel will before long be resumed.

Again, the *Davout*, a second-class cruiser of 3,027 tons displacement, which was built by the Government at Toulon, and launched in 1889, commenced her trials at sea in March, 1891, but is now in the arsenal, where large alterations are being made in the engines, built by the Government at Indret, and the hull of the vessel, which has been found to have been too lightly constructed for the power of the engines, is being considerably strengthened and stiffened. The *Davout* was designed to give a speed of 20 knots per hour under forced draft, and a speed of 18 knots per hour under natural draft. The results of the trials made for the latter speed have so far been satisfactory, but those made for the maximum speed have proved altogether a failure.

The *Sfax*, which is frequently spoken of as being one of the most powerful cruisers of the French Navy, is a composite vessel, launched at Brest in 1884, and is stated to have given a maximum speed of 16.84 knots per hour on her trials, whilst at present it is with the greatest difficulty that she can run a voyage of any length at 12 knots per hour without the main and other bearings of the engines becoming excessively hot, necessitating a very copious supply of water, in addition to being a most uncomfortable ship to the engineering staff, owing to the great heat experienced in the engine rooms when the ship is under steam.

The *Forbin*, sister ship to the *Coetlogon*, *Cosmas* and *Surcouf* was built and engined by the Government, and was launched in 1888. She has a displacement of 1,850 tons, and on her trial gave a maximum speed of over 20 knots. This vessel, after about two years in active service, was found to have seriously damaged herself and her engines by the excessive vibration, and was put into the Toulon arsenal to undergo general repairs, and for the strengthening throughout of her hull. This vessel, in addition, is most inconveniently arranged internally, carries very little coal, and this is so disposed as to render it very difficult of access.

And, lastly, comes the *Milan*, a third-class cruiser of 1,540 tons, launched in 1886. Built and engined by the Government, this vessel attained a speed of 18 knots on her trials, and after four or five years of light service with the fleet, it has been found necessary to take out of the hull both the engines and the boilers, renewing the latter, and largely rebuilding and modifying the former, which, according to accounts received, have never given much satisfaction.

A similar list might be made of ironclads and torpedo boats in the French Navy, which have undoubtedly, in proportion to the number built, given as much, or very much more trouble and anxiety to those connected with their construction than has been endured by English constructors and engineers connected with the design and construction of modern British ships.

Masséna.—This new battleship is to be built by the Société

des Chantiers de la Loire, and, according to the terms of the contract, is to be completed within five years. The plans have been prepared by M. de Bussy, who has designed all the most recent French ironclads. The principal dimensions of the vessel will be: Length, 366 feet 4 inches; beam, 65 feet 6 inches; draught of water aft, 26.2 feet; displacement, 11,700 tons. There will be three screws driven by engines which, with 16 boilers, will develop under forced draft a maximum of 11,000 H.P., and a speed of 18 knots. There will be a complete waterline belt of armor of a maximum thickness of 17.7 inches. The armament will be as follows: Two 11.8 inch guns, one forward and the other aft, in covered barbettes; two 10.6-inch guns in covered sponson barbettes, one on each broadside; eight 5.5-inch quick-firing guns in sponsons, four being on each broadside; four smaller quick-firing guns of 3.3 inch (20-pdrs.), four of 2.9 inch (9-pdrs), and 12 1.8 inch (3-pdrs.); and ten Hotchkiss revolving cannon of 1.46 inch (1-pdrs.). The vessel will have four torpedo ejectors, two forward and two aft, and will be the first ship in the French navy to be provided with submerged tubes. A sister ship of the *Massêna* will be laid down later in the year.

Torpedo Boat.—On February 3d, 1892, *Torpedo Boat 155*, built at Lorient, France, was launched. This vessel is 118 feet long, 13 feet 1½ inches beam, and 3 feet 11½ inches draught, with a displacement of 80 tons. Her engines are of 1,000 I.H.P., and the speed contracted for is 21 knots.

JAPAN.

Itsukushima, Matsushima and Hashidate.—The *Matsushima* is one of the three sister ships designed by Monsieur Bertin (a French naval architect) for the Japanese navy at the time he was Chief Naval Constructor to the Japanese government; and, with the *Itsukushima*, has been built and fitted out at La Seyne under the inspection of the Japanese officials appointed for the purpose. The third ship, the *Hashidate*, has been built and fitted out in the Japanese government arsenal at Yokosuka, much of the machinery, the guns and gun fittings and appliances being sent out from Europe.

Below the waterline the three ships are identical in design; but above this line the *Matsushima* differs from her two sisters in that she has the 65-ton gun, carried by each vessel, mounted aft of the funnel, instead of forward, as is done on both the *Itsukushima* and the *Hashidate*.

Below are the principal particulars of the three ships: Length, 324 feet 10 inches; beam, 50 feet 10 inches; depth, 35 feet; draught (mean), 21 feet 2 inches; displacement, 4,277 tons; specified speed, 16 knots; specified H.P., 5,400.

The ships are deck-protected throughout their entire length, but carry no side armor. Thirty centimeter (11.8 inch) Creusot steel armor is fitted to the barbette tower of the heavy gun, and, as a further protection, the ships are extensively divided into watertight compartments. Mild steel has been used throughout as the material of construction. The mast, placed aft of the funnel, is also of steel, and is supported by tripods of steel plate, shrouds being dispensed with. Double military tops, armed with quick-firing and machine guns, are fitted to the mast, and above these a pine top-mast is rigged for signal service. Access is given to the tops solely by means of an iron ladderway, running vertically up the mast, to which it is attached on the after side, the interior of the mast being occupied by an ammunition hoist for the service of the guns in the tops.

Four electric search-light projectors are fitted, one on each end of the fore bridge, one forward and one aft on the upper deck; whilst the electric light is further used for the interior lighting, the mast-head and side-lights of the ship. Bullivant's torpedo-defence netting is supplied as a protection against a torpedo attack, and a conning tower for the protection of the commander in time of action, is built on the fore bridge, forward of the funnel.

The ships are each propelled by means of two three-bladed propellers; and, following the practice of the French Navy, those parts of the propeller shafts outside the ship have been sheathed in brass to prevent corrosion. The propellors are driven by two triple-expansion three-cylinder engines of the horizontal type, situated in two engine-rooms, one forward of the other. Steam

is supplied by six cylindrical boilers, arranged in two groups of three, placed athwartships, each boiler having three corrugated furnaces of the Fox pattern.

The armament consists of one 32-centimeter (12.6-in.) Canet B.L.R. gun, with a weight of 65 tons, and a length of 42 feet. The projectiles are of chrome steel; and, fired by means of smokeless powder, have, it is calculated, sufficient power to pierce four feet of iron armor at the muzzle. There are ten 12-centimeter (4¾-inch) Armstrong B.L.R. guns in the battery on the main deck, and one of the same bore mounted aft in the *Itsukushima* and *Hashidate*, and forward in the *Matsushima* on the upper deck. Six quick-firing and twelve single-barrelled machine guns of the Canet system, two of the latter being mounted in the lower of the two military tops, and four torpedo-discharging tubes, firing Whitehead torpedoes, complete the armament. These tubes are situated, one forward, one right aft, one on the starboard side, and one on the port side, just forward of amidships. The whole of the fittings and apparatus for mounting and working the 32-centimeter gun are of the Canet system, which has been supplied with very great success by the Société des Forges et Chantiers de la Méditerranée to many ships built by them for the French and foreign governments.

The first completed of the three ships was the *Itsukushima*, which was launched at La Seyne in the spring of 1889, and commenced her steam trials in the month of September of the following year, a maximum speed of 16.54 knots per hour being obtained, an excess of over half a knot per hour on the speed guaranteed by the contractors. The gun trials throughout gave very great satisfaction to the Japanese officials, and these having been terminated, the ship left for Japan about four months ago.

Also built at La Seyne, and engined by the builders of the hull, the *Matsushima* was launched some three or four months after the *Itsukushima*, and on her speed trials exceeded the contract speed, but proved herself exceedingly hot when under steam. She will shortly sail for Japan.

The Chishima-Kan.—The new Japanese torpedo gun-vessel

Chishima-Kan, which was launched at St. Nazaire on November 27th, 1890, and which, with a displacement of 753 tons, has an extreme speed of 22 knots, has left the Loire, and, after receiving her armament, will depart for Japan.

SPAIN.

Temerario.—The new Spanish torpedo gun-vessel *Temerario*, which was built at Carthagena, and which is a sister to the *Audaz* and *Nueva Espana*, building at Caracas, and to the *Veloz*, *Galicia*, and *Rapido*, building at Ferrol, has made on her trials 16.5 knots with natural and 20.5 knots with forced draft. The dimensions of each of these six vessels are: Length, 190 feet 3 inches; beam, 22 feet 11 inches; draft, aft, 10 feet 4 inches; displacement, 550 tons. There are two cylindrical and two locomotive boilers. With the two ordinary boilers 650 H.P. can be developed.

AUSTRIA.

Pelican.—This vessel is a torpedo-depot ship, similar to the *Vulcan* of the English Navy, though not so large. Her displacement is about 3,000 tons. The hull and machinery have been built by Schichau, the well-known torpedo-boat builder, of Elbing, Germany. The contract called for 16.5 knots and 4,500 I.H.P. under natural draft, but on trial the speed was 18.3 knots, with an I.H.P. of between 4,700 and 4,800. Provision is made for forced draft if desired. The engines have cylinders 33.9, 55.1 and 84.6 inches in diameter by 39.37 inches stroke. They are of the usual vertical triple-expansion type, and built light in accordance with torpedo-boat practice. There is only one screw, somewhat of a departure from the general practice in modern naval vessels. All the valves are of the piston type, and to save room are on the sides of the cylinders, the H.P. being on one side and the others on the opposite. They are driven by Joy's valve gear. There are two boilers of the double-ended type working at 165 pounds pressure, with six furnaces each. The length is 18 feet 4½ inches and the diameter 14 feet 5¼ inches. The following are the trial data: Boiler pressure, 165 pounds; vacuum, 27.25 inches; revolutions, 140; mean pressures, H.P.,

58.87; I.P., 23.60; L.P., 10.20; I.H.P., H.P., 1,490; I.P., 1,590; L.P., 1,620—total, 4,700. The average coal consumption on trial is said to have been 1.65 pounds per I.H.P.

GREECE.

Spetzia.—The new Greek iron-clad *Spetzia*, which was launched at Gréville on October 26th, 1889, and which on her trials maintained a mean speed of 17.5 knots during a three-hours' run, left France recently for the Piræus. She is of 4,885 tons displacement and 6,930 I.H.P., and is 334 feet in length by 51 feet 10 inches beam. She carries two 10.6-inch guns of 36 calibers, one 10.6-inch gun of 30 calibers, and five 5.9-inch guns of 36 calibers, all Canets. There are also seven 6-pounder Hotchkiss quick-firing guns and sixteen 1-pounder Hotchkiss revolving cannon, with three torpedo ejectors. The complement of officers and men is 400. The *Spetzia* is the second of three sister ships to be delivered to Greece from French private yards. The first was the *Hydra*. The *Psara*, launched at Gréville on February 20th, 1890, is not yet quite finished.

MERCHANT STEAMERS.

City of New York and City of Paris.—In consequence of the Act of Congress given below, it seems likely that these two magnificent vessels will very soon fly the American flag. Indeed, it will be seen from the terms of the act that they are the only ones which could profit by it, as they are the only vessels of over 8,000 tons register owned by companies nine-tenths of whose stock is held in the United States. It is not absolutely certain that they will be transferred to this country, as it seems that in the contract made with the British Government by which they received a subsidy on account of being built so as to be available as auxiliary cruisers in time of war, it was provided that if at any

time the owners desired to terminate this contract, the government should have the option of purchasing them. It does not seem at all probable, however, that this will occur.

Since the passage of this bill, a similar one has been introduced looking to the granting of an American register to the *China* of the Pacific Mail Line, which was built in England and now flies the Hawaiian flag, and there is no doubt that it will pass. A bill has also been introduced providing that "The American Steamship Company" may purchase or otherwise procure foreign-built steamers of not less than 7,000 tons register with a speed of not less than 19 knots, provided an equal number of similar vessels are built in American shipyards.

It will be seen that these acts provide for a considerable increase at once of fine vessels under our own flag, and as there is no opposition to the method from either of the political parties we may not unreasonably expect it to continue, so that patriotic pride will have a chance to be gratified by the more frequent appearance of our flag in foreign ports.

"AN ACT TO ENCOURAGE AMERICAN SHIPBUILDING.

"*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That the Secretary of the Treasury is hereby authorized and directed to grant registers, as vessels of the United States, to such foreign-built steamships now engaged in freight and passenger business, and sailing in an established line from a port in the United States, as are of a tonnage of not less than eight thousand tons, and capable of a speed of not less than twenty knots per hour, according to the existing method of Government test for speed, of which not less than ninety per centum of the shares of the capital of the foreign corporation or association owning the same was owned January first, eighteen hundred and ninety, and has continued to be owned until the passage of this act by citizens of the United States, including as such citizens corporations created under the laws of any of the States thereof, upon the American owners of such majority interest obtaining a full and complete transfer and title to such steamships from the foreign corporations owning the same: *Provided*, That such American owners

shall, subsequent to the date of this law, have built or have contracted to build, in American shipyards, steamships of an aggregate tonnage of not less in amount than that of the steamships so admitted to registry. Each steamship so built or contracted for to be of a tonnage of not less than seven thousand tons.

"SEC. 2. That the Secretary of the Treasury, on being satisfied that such steamships so acquired by American citizens, or by such corporation or corporations as above set forth, are such as come within the provisions of this act, and that the American owners of such steamships, for which an American registry is to be granted under the provisions hereof, have built or contracted to build in American shipyards steamships of an aggregate tonnage as set forth in the first section hereof, shall direct the bills of sale or transfer of the foreign-built steamships so acquired to be recorded in the office of the collector of customs of the proper collection district, and cause such steamships to be registered as vessels of the United States by said collector. After which, each of such vessels shall be entitled to all the rights and privileges of a vessel of the United States, except that it shall not be employed in the coastwise trade of the United States.

"SEC. 3. That no further or other inspection shall be required for the said steamship or steamships than is now required for foreign steamships carrying passengers under the existing laws of the United States, and that a special certificate of inspection may be issued for each steamship registered under this act; and that before issuing the registry to any such steamship as a vessel of the United States the collector of customs of the proper collection district shall cause such steamship to be measured and described in accordance with the laws of the United States, which measurement and description shall be recited in the certificate of registry to be issued under this act.

"SEC. 4. That any steamships so registered under the provisions of this act may be taken and used by the United States as cruisers or transports upon payment to the owners of the fair actual value of the same at the time of the taking, and if there shall be a disagreement as to the fair actual value at the time of taking between the United States and the owners, then the same

shall be determined by two impartial appraisers, one to be appointed by each of said parties, who in case of disagreement, shall select a third, the award of any two of the three so chosen to be final and conclusive."—Approved May 10, 1892.

New Hampshire.—This fine vessel and her twin sister, the *Maine*, were built by the Harlan & Hollingsworth Co., of Wilmington, Delaware, for the Stonington Line of Sound steamers, and represent something of a departure in the Sound passenger boats, where side-wheel vessels have hitherto been almost the only ones used, while these are propellers. The order for them was placed with the Harlan & Hollingsworth Co. in May of 1891. The *Maine* was delivered to the owners early in March of this year, and the *New Hampshire* on April 25th.

The hull dimensions are, 295 feet on water line by 44 feet by 11 feet 1½ inches mean draught; displacement, 2,450 short tons or 2,200 tons of 2,240 pounds.

The main saloon on the promenade deck has 102 state rooms, including several large rooms, elegantly finished in hard wood, and fitted with brass bedsteads instead of the usual double bunks. On the deck above the main saloon are the dining room, café, pantry, galley, &c., which is again a radical departure from existing methods, where these are on the deck below the main saloon.

The engine is a four-cylinder triple-expansion, of the usual vertical inverted type. The diameters are 28, 45 and two of 51 inches, with a common stroke of 42 inches. All the cylinders have piston valves worked by Stephenson links. There are four single-ended cylindrical boilers built for a working pressure of 160 pounds. The diameter is 13 feet 6 inches and the length 11 feet 6 inches. Each boiler has three furnaces, 46 inches outside diameter. The total grate surface is 274 square feet, and the total heating surface 7,780 square feet—a ratio of 28.5 to 1. Blowers are fitted to be used if necessary, but the expectation is that, with good coal and clean fires, ample power can be obtained with natural draft, as was the case on the trial trip, which took place April 21st.

During the trial four runs were made over the measured mile (5,280 feet), with the following results:

	Time.	Rev's.	Mean speed.	Mean I.H.P.	$\frac{V^3 \times D^{\frac{2}{3}}}{I.H.P.}$
	Min. Sec's.				
Down, .	3 04	98	18.23	2,766	398
Up, .	3 33	99			
Down, .	2 59	101	18.46	2,923	392
Up, .	3 34	101			

These are for speeds in statute miles and displacement in short tons. Taking knots and long tons, we get for mean of all four runs 15.99 knots and constant = 243.

A set of cards taken during the last run gave: Steam pressure, 158 pounds; 1st receiver, 65 pounds; 2d receiver, 11 pounds; vacuum, 28 inches; throttle, wide; mean pressures, H.P., 66.6; I.P., 31.3; 1st L.P., 12.1; 2d L.P., 10.7; mean pressure referred to L.P., 33.6. Horse powers, H. P., 878.76; I.P., 1,066.5; 1st L.P., 529.56; 2d L.P., 468.23—total, 2,943.05.

The information and data have been kindly furnished by T. Jackson Shaw, Esq., superintending engineer of the Harlan & Hollingsworth Co.

The New Cunarders.—While no general description of the two "five-day" steamers for the Cunard Line has yet appeared, some items of interest are leaking out. It is learned that the boilers are to be at least 17 feet in diameter (some rumors say 17 feet 6 inches), and that the shell plates are $1\frac{7}{8}$ inches thick, the greatest yet used. These shell plates are 9 feet 6 inches by 15 feet, and weigh about 4 tons. The ingots from which they are made weigh 6 tons. It is understood that the working pressure will be 160 pounds.

Comanche.—The steel yacht *Comanche*, built for Mr. H. M. Hanna, was launched from the yards of the Globe Iron Works Company of Cleveland, Ohio, a few months ago, and is now approaching completion.

The *Comanche* is termed an auxiliary yacht, being a full-

powered sail vessel, but should strictly, owing to her large engine capacity and complete machinery, be called a steam yacht; she will be efficient as both. Dimensions are as follows: Length over all, 184 feet 6 inches; length load line, 165 feet; breadth moulded, 25 feet; depth moulded, 14 feet 3 inches. She carries two masts and a brigantine rig, and the propelling machinery consists of a triple-expansion engine for 160 lbs. steam pressure.

Four water-tight bulkheads extending up to the main deck divide the ship into five water-tight compartments. On this deck is located a deckhouse enclosing engine room, skylight, upper boiler room with donkey boiler, galley, armory, charthouse, and a deck saloon with smoking room, etc. On the deck below, called the cabin floor, are located, beside the owner's dining saloon, all living quarters, two large staterooms amidships, forward of which six other rooms and smaller compartments for various purposes are well arranged. Aft are living accommodations for captain, officers and crew. Electric lights furnished from a double plant will be provided everywhere in the ship. Four boats, of which one is a steam launch, will be placed on a level with the top of the house, where the bridge and steering wheel are located. Forward is an anchor deck and a capstan, the steering apparatus being an improved patent hand steerer. In the hold are two tanks of 25 tons each (one of which is for fresh water), baggage rooms and coal bunkers.

The main engine, which is of the inverted direct-acting, vertical triple-expansion type, actuates a cast-iron wheel with adjustable blades 9 feet diameter and 10 feet 6 inches pitch.

Sizes of cylinders are 14, 23 and 36 inches, by 24 inches stroke. They are set up on three single cast-iron columns at the back and four turned wrought-iron columns in front. The valve chests are all on the working side, with spring piston valves for H.P. and I.P. and a double-ported slide for L.P. All valves are accessible from the side, top and bottom, bonnets being done away with. They are all fitted with the Joy radial valve gear, of which the bearings for links and reverse arms in this case rest on a polished steel angle bolted to the lower end of the front columns. The reversing engine, recessed into the

bed plate and bolted to it, is of the "push-and-pull" type, but without oil or water regulating cylinder. The crank shaft is built up and forms with the thrust shaft one length; it is laid in six main bearings lined with white metal. The thrust block has adjustable horse-shoe yokes, and is bolted direct to the bed plate. The air pump is worked from the L.P. cylinder crosshead by means of beams and drag links; two feed pumps, one bilge pump, and one cold-water pump are connected to the air pump crosshead. The condenser is placed abaft the main engine, on the port side. It has a tube surface of about 800 square feet; it is circular, and built up of wrought iron plates with cast-iron flanges and heads, tubes and tube sheets being of composition. An independent circulating-pump with 7-inch diameter suction operates the condenser. All steam, feed and water pipes are copper; drainage pipes galvanized wrought iron.

One Scotch boiler 12 feet in diameter and 9 feet long, with three 36-inch Adamson's furnaces, supplies steam for the main and auxiliary machinery. A small donkey boiler placed on the main deck will furnish steam for operation of heating and ventilating systems when the large boiler is not working.

Crank shaft and line shafting, columns, reverse shaft, connecting rods and valve-connecting links are made of wrought iron; piston rods, valve stems and small gear of machinery, of steel; links of cast iron and link blocks of steel. There is a total heating surface in the boiler of 1,235 square feet and 45 square feet of grate surface. At 140 turns the main engine is calculated to develop about 550 I.H.P.

The *Duke of Clarence*, which has been built for the joint line of the London and Northwestern and the Lincolnshire and Yorkshire Railway Cos., is a twin-screw steamer, designed to combine the qualifications of a first-class mail and passenger vessel with good cargo capacity, and superior fittings for a moderate number of horses or cattle on the upper deck. The scantlings have been made especially strong, and the hull is divided into eight water-tight compartments by seven transverse vertical steel bulkheads, which extend from the keel to the main deck; and the latter being also of steel for about seven-eighths

of its length, it will be seen that the ship has been made practically unsinkable. On the main deck there is a long, closed-in midship house, forecastle and full poop, the sides between these being carried right up to the spar deck, for the better protection of the cattle and horses, so that the general appearance of the vessel is that of a spar-decker. There is a straight stem and elliptic stern, and the vessel is schooner rigged, with two taut steel pole masts, and one very large funnel. The dimensions are: 320 feet over all, 311 feet between perpendiculars; beam 36 feet; depth, moulded, 17 feet 3 inches; depth of hold, 15 feet, 9 inches; with a gross tonnage of 1,500, and a net register tonnage of 530. Trimming tanks are provided in the forward and after peaks, holding 40 and 60 tons respectively, while the midship tank holds 160 tons. Bilge keels are fitted to minimise the rolling. The main engines have been designed and built by Messrs. Laird, and consist of two sets of ordinary triple-expansion engines with inverted cylinders, the dimensions being 22, 34 and 51 inches by 33 inches stroke. The ordinary valve gear is fitted, and the L.P. valves have Joys' assistant cylinders. Steam is supplied to all the engines from two double-ended cylindrical boilers, measuring 14 feet 9 inches by 18 feet 6 inches, and there are six furnaces. The fire rooms have been adapted for forced draft, air of any requisite pressure being supplied by two large fans on the spar deck. It may be mentioned that each propeller has four blades of manganese bronze.

The vessel is sumptuously fitted up in every respect. The accommodation for first-class passengers is situated amidships, forward of the engines, the amidship part of the spar deck or bridge deck affording a magnificent wide promenade 130 feet in length, while above this, on the captain's bridge, there is also a fine, roomy and lofty promenade. The roof of the house on the spar deck is carried out to the sides, affording accommodation for the lifeboats and shelter for the promenade. From the spar deckhouse the passengers enter the saloon by a roomy, handsome stairway of polished oak, and the saloon entrance is fitted with artistic looking india rubber tiling. The saloon itself, which is on the main deck, is a most luxurious apartment,

about 36 feet square, and every inch of space has been utilized to the best possible effect. Perhaps the feature of the vessel is the large number of elegantly-furnished and well-appointed state rooms throughout the first-class accommodation, there being no less than 31 of these handy and comfortable apartments, some to hold eight persons, and others with accommodation for four, the whole first-class "sleeping power" being over 200.

The derrick and lifting gear generally is very complete, and it is estimated that about 220 tons of cargo can be carried. Of the life-saving appliances, in addition to the 864 life belts, there are six life boats, Section A, and two of Copeman's buoyant deck seats, the very highest requirements of Lloyd's and the Board of Trade being more than satisfied. The electric lighting arrangements are most efficient and complete. The engine, which is located in the bulkhead aft of the main engines, is one of Shank's ordinary horizontal type, with a 5 feet 6 inches diameter flywheel, the belt running on to a dynamo of the Edison-Hopkinson type, manufactured by Mather & Platt, and giving 250 amperes at 55 volts, the revolutions being about 700. The switch board is divided into four circuits, with measuring instruments in circuit. These are run respectively to the arc search light, the engine room, cargo, and masthead lights, the lower deck staterooms and passages, and saloon, main deck, and poop. There are 215 lamps throughout the ship, chiefly of eight candle power, and two cargo clusters. The arc search light, which is placed in the bow, is fitted with a magnificent Chance mirror, the power being of 5,000 candles, and it is capable of throwing a light about half a mile. During her initial trials, the *Duke of Clarence* attained a speed of 17.2 against the tide, and 20.2 with the tide, making an average speed of 18.8 knots per hour. The I.H.P. developed was about 4,000; boiler pressure, 160 pounds, and the maximum revolutions 150 a minute. The average forced draft was 1 inch of water pressure. Throughout, the engine ran with remarkable smoothness, and the bearings kept perfectly cool. The vessel was drawing about 10 feet 3 inches forward, and 11 feet 6 inches aft.—"Marine Engineer."